Food Science

Third Edition

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Chapter 1

INTRODUCTION TO FOOD SCIENCE

Man must eat to live and what he eats will affect in a high degree his ability to keep well, to work and to live long. Food performs many vital functions in the body.

FUNCTIONS OF FOOD

Foods are classified according to their functions in the body.

Energy yielding

This group includes foods rich in carbohydrate, fat and protein. One gram of carbohydrate gives 4 calories. One gram of protein gives 4 calories. One gram of fat gives 9 calories. They may be broadly divided into two groups:

i. Cereals, pulses, roots and tubers

ii. Pure carbohydrates like sugars and fats and oils.

Cereals provide in addition to energy large amounts of proteins, minerals and vitamins in the diet. Pulses also give protein and B vitamins besides giving energy to the body. Roots and tubers though mainly provide energy, they also contribute to some extent to minerals and vitamins.

Pure carbohydrates like sugars provide only energy (empty calories) and fats also provide concentrated source of energy.

Body building

Foods rich in protein are called body building foods. They are classified into two groups:

i. Milk, egg, meat, fish: They are rich in proteins of high biological value. These proteins have all the essential amino acids in correct proportion for the synthesis of body tissues.

ii. Pulses, oil seeds and nuts: They are rich in protein but may not contain all the essential amino acids required by the human body.

Protection and regulation

Foods rich in protein, vitamins and minerals have regulatory functions in the body e.g., maintaining the heart beat, water balance, temperature. Protective foods are broadly classified into two groups.

i. Foods rich in vitamins and minerals and proteins of high biological value e.g., milk, egg, fish, liver.

ii. Foods rich in certain vitamins and minerals only e.g., green leafy vegetables and some fruits.

Maintenance of health

Food contains certain phytochemicals and antioxidants which help in preventing degenerative diseases. Food plays an important role in the prevention of cancers, heart diseases and in controlling diabetes mellitus.

Some examples for functional foods are whole grains, soyabean, green leafy vegetables, coloured fruits and spices.

FOOD GROUPS

Foods have been classified into different groups depending upon the nutritive value, for the convenience of planning meals. Food groups like 'Basic four', 'Basic five' or 'Basic seven' can be used for planning meals as per the convenience.

I. Basic Four

Group	*Nutrient*
• Cereals, millets and pulses	Energy, protein B-vitamins
• Vegetables and fruits	Vitamins, minerals and fibre
• Milk, milk products, and animal foods	Protein, calcium B-vitamins
• Oils, fats, nuts and oilseeds	Energy, protein (nuts and oil seeds).

II. Basic Five: ICMR

• Cereals, grains and products: rice, wheat, ragi, maize, bajra, jowar, rice flakes, puffed rice.	Energy, protein, invisible fat, thiamin, folic acid, riboflavin, iron and fibre.
• Pulses and legumes: Bengal gram, black gram, cow pea, peas (dry) rajma, soyabeans.	Energy, protein, invisible fat, thiamin, riboflavin, folic acid, calcium, iron and fibre.
• Milk and meat products:	Protein, fat, riboflavin,
i. Milk, curd, skimmed milk, cheese	calcium, protein, fat, riboflavin.
ii. Chicken, liver, fish, egg and meat.	

be pleasing in appearance and taste so that it is consumed. Understanding food behaviour in scientific terms helps in choosing best method of cooking. Food preparation is an important step in meeting the nutritional needs of the family.

Foods like fruits, vegetables and nuts are eaten raw but most of the foods are cooked to bring about desirable changes.

The process of subjecting foods to the action of heat is termed as cooking.

OBJECTIVES OF COOKING

Improves the taste and food quality

Cooking improves natural flavour and texture of food. For example roasting groundnuts, frying onions and papads, cooking rice and roasting coffee seeds improve the flavour. Cooking meat with spices, rice with spices in making pulav, frying cashewnuts in ghee, addition of turmeric, curry leaves, pepper in pongal, blend flavour with one another during cooking.

Too much of cooking lowers the flavour as flavouring compounds are volatile. Over-cooked pulav, does not taste as good as well cooked pulav.

Destruction of microorganisms

Microorganisms are present everywhere and some are useful in making curd, cheese and bread. Some are harmful and cause infections or produce toxins, e.g. clostridium botulism and salmonella. Some moulds produce toxins. Aspergillus flavus produces aflatoxin in groundnuts, cereals and spices. This aflatoxin is a health hazard.

One of the most important methods of protection of food against harmful microorganisms is by the application of heat. Cooking food to the required temperature for a required length of time can destroy all harmful microorganisms in food e.g. pasteurised milk.

Tapeworm or its larvae which infest pork can be killed by proper application of heat. By cooking, food is made safe for consumption.

Improves digestibility

Cooking softens the connective tissues of meat and the coarse fibres of cereals, pulses and vegetables so that the digestive period is shortened and gastrointestinal tract is less subjected to irritation. Cooking improves the texture hence it becomes more chewable. Cooking also bursts the starch granules of pulses and cereals so that the starch digestion is more easier, rapid and complete. When dry heat is applied to starches they are converted to easily digestible dextrins. Cooking increases the access to enzymes and improves digestibility.

Increases variety

By cooking, same food can be made into different dishes. For example, rice can be made into plain, pulav, lemon rice, biryani, or combination with pulses and idli. Wheat can be made into chapatis, puri, paratha or halwa.
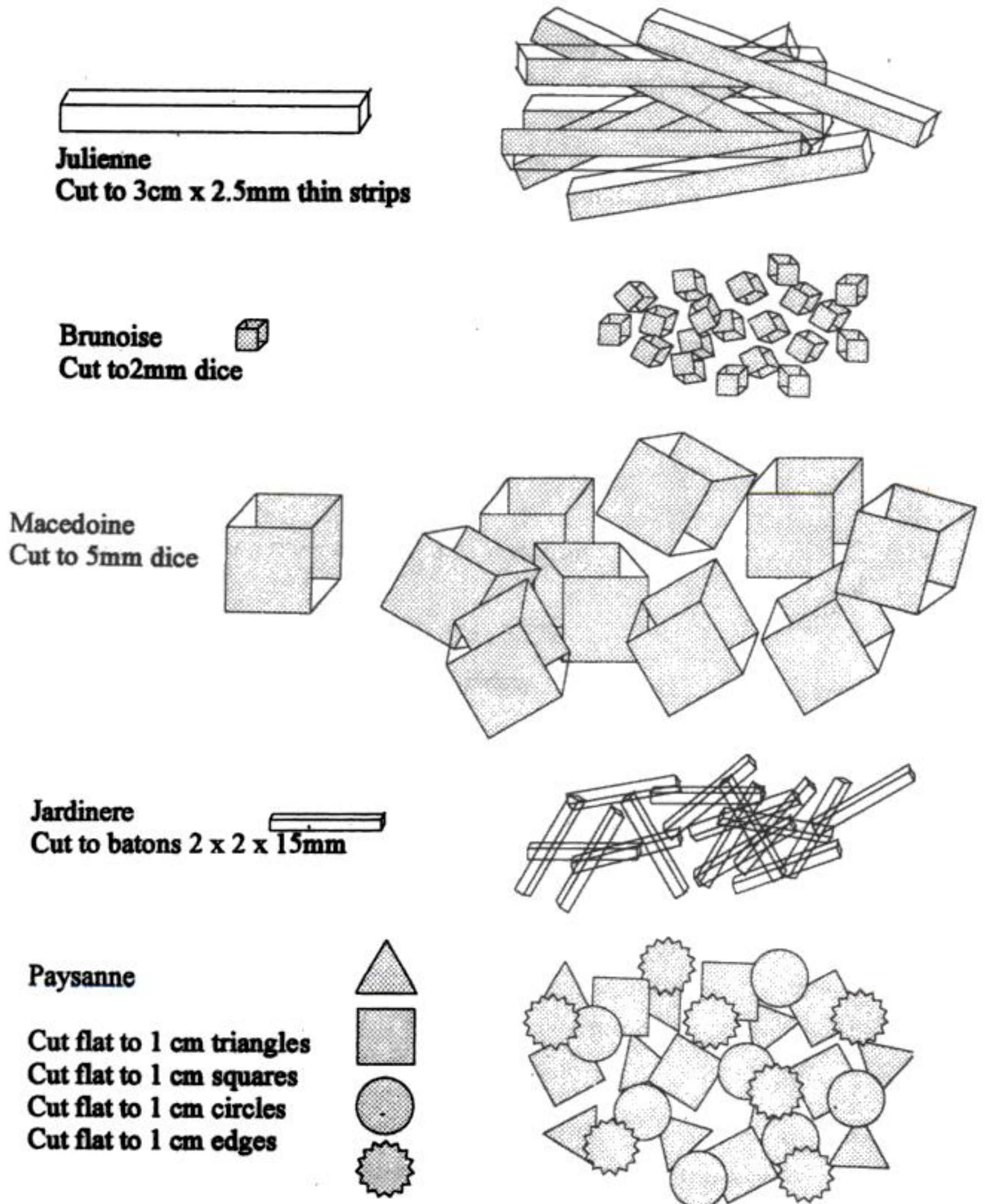
Figure 1-b: Standard vegetable cuts.

Source: Ursula Jones, 1986, Catering: Food preparation and service, Edward Arnold Ltd., London.

- The coat of breading helps in transmission of heat to the food product.
- It brings less fat absorption.
- Produces a crunchy texture.
- Helps the food to retain moisture.
- They help in binding the food substances.

Disadvantages:

- Battered or dredged food cannot be held long, otherwise the product becomes soggy.
- Breading may not stick to food.
- The breading may break during frying.

Blanching: This is plunging food into boiling liquid and immersing in cold water. This destroys enzymes present in food hence used as preparation for preservation. Food products normally blanched are tomatoes, potatoes, almonds, carrots and beans.

Advantages:

- Peel can be removed easily.
- It is a preliminary method for canning and freezing.
- Microorganisms present on the surface are partially removed.
- Enzymes bringing spoilage can be inactivated.
- Blanching causes better exposure of pigment, hence improves the colour of the food product.

Disadvantages:

- Part of water soluble nutrients may be lost.
- Long time blanching undesirably softens the food.

Marinating: Marinating is soaking a food in a marinade to add flavour or to tenderize it or both. A marinade is any liquid made up for purpose of marinating. Vegetables, fruits and meats are marinated with many flavour combinations. Meat marinade made up of oil, flavour builders and acid. Oil helps to hold natural juices of meat. Acid is used to tenderize by breaking down connective tissue. Vegetables normally marinated are brinjal, onions, radish, bittergourd, potatoes and chillies.

Advantages:

- Prevents browning reaction e.g. in potatoes and apples.
- Adds flavour to the food.
- Texture of product is improved.

Advantages:

- It is the most simple method. It does not require special skill and equipment.
- Soluble starches can be removed and rice grains are separated.
- Protein gets denatured, starch gets gelatinized and collagen gets hydrolysed.
- Uniform cooking can be done.

Disadvantages:

- Loss of nutrients: If excess water is used in cooking and the water is discarded 30-70% water soluble nutrients like vitamin C may be lost. To prevent this type of losses, cooked water should be used in soups, rasam, sambhar and dhal. Some protein may be lost if vegetables are cooked in water containing salt and the cooking water is discarded. There is considerable loss of minerals especially sodium, potassium and calcium due to leaching.
- Loss of colours: Water soluble pigments, like betanin from beetroot may be lost. Beetroot should be cooked along with the skin to prevent the loss of colour.
- Time consuming: Boiling may take time and fuel may get wasted.
- Loss of flavour and texture: Boiled foods are not considered tasty because flavour compounds are leached into the water. Over-boiling of food may make the food mushy.

Simmering

When foods are cooked in a pan with a well fitting lid at temperature just below the boiling point 82-99°C of the liquid in which they are immersed the process is known as simmering. It is a useful method when foods have to be cooked for a long time to make it tender as in the case of cheaper cuts of meat, fish, cooking custards, kheer, vegetables and carrot halwa. This method is also employed in making soups.

Advantages:

- Foods get cooked thoroughly.
- Scorching or burning is prevented.
- Losses due to leaching is minimum.

Disadvantages:

- There is loss of heat-sensitive nutrients, due to long period of cooking.
- Takes more time and more fuel is required.

Poaching

This involves cooking in the minimum amount of liquid at a temperature of

The term toasting is used to describe a process by which bread slices are kept under the grill or between the two heated elements to brown from both sides of the bread at the same time. This can be adjusted to give the required degree of brownness through temperature control.

Advantages:

- Quick method of cooking.
- Less or no fat is required.
- Flavour is improved.

Disadvantage:

- Constant attention is required to prevent charring.

Pan broiling or roasting

When food is cooked uncovered on heated metal or a frying pan the method is known as pan broiling, e.g. groundnuts and chapatis.

Advantages:

- Improves the colour, flavour and texture of the food.
- Reduces the moisture content of the food and improves the keeping quality, e.g. rava.
- It is easy to powder e.g. cumin seeds and coriander seeds after roasting.
- It is one of the quick methods of cooking foods.

Disadvantages:

- Constant attention is required.
- Losses of nutrients like aminoacids occur when the food becomes brown.

Baking

Here food gets cooked by hot air. Basically it is a dry heat method of cooking but the action of dry heat is combined with that of steam which is generated while the food is being cooked. Foods baked are generally brown and crisp on the top, soft and porous in the centre, e.g. cakes, pudding and breads. The principle involved in baking is the air inside the oven is heated by a source of heat either electricity or gas or wood in case of tandoori. The oven is insulated to prevent the outside temperatures from causing fluctuations in internal temperatures of the equipment. The methods of heat transfer involved are radiation from the source of heat to the metal wall at the base of the oven, by conduction from the base to the other walls and by convection through the heated air currents set up in the oven to the food. The temperatures that are normally maintained in the oven are 120°C - 260°C. Foods prepared by baking are custards, pies, biscuits, pizzas, puffs, buns, bread, cakes, tandoori chicken, tandoori meat and fish.

fruits. Leftovers from the previous day's dinner can be heated in a minute and reused for breakfast or lunch. Precooked processed foods available in Indian markets like tikkas, kababs, dhals and chicken curry can be on the table in minutes.

Following the instructions supplied by the manufacturers home makers can make a cake in 8 minutes and chicken tikkas in about the same time. Stuffed capsicum are ready in 6 minutes only. Some microwave ovens have an infrared lamp fitted into the oven cavity so that exterior colouring can be induced while the microwave heating is occurring.

An alternate method that is currently being developed in domestic microwave ovens is to lengthen the cooking time by reducing the microwave output. In this way the longer cooking time allows some surface colouring to occur so that the appearance of the food matches the conventional product more closely. The increase in cooking time (2-4 fold) still allows a significant saving over conventional cooking time.

PRACTICAL HINTS IN USING MICROWAVE OVEN

- Do not use the oven for home canning or the heating of any closed jar. Pressure will build up and the jar may explode.
- Small quantities of food or foods with low moisture content can dry out, burn or catch on fire.
- Do not dry meats, herbs, fruits and vegetables in the oven.
- Do not attempt to deep fry in microwave oven. Cooking oils may burst into flames. Microwave utensils may not be able to withstand the temperature of the hot oil and could shatter.
- Do not heat eggs in their shell in microwave oven. Pressure will build up and the eggs will explode.
- Potatoes, apples, egg yolks and whole vegetables must be pierced before microwave cooking to prevent bursting.
- Overcooking of vegetables like potatoes cause dehydration and fire.
- Heated liquids can erupt if not mixed with air. Do not heat liquids in microwave oven without first stirring.
- Do not use paper towels or clothes which contain a synthetic fibre woven into them. The synthetic fibre may cause the towel to ignite.
- Do not use paper bags or recycled paper products in the microwave oven.
- Do not heat narrow mouthed containers as the liquid may boil over even after cooking has stopped.
- Do not leave open unattended while in use.
- Both bone and fat affect cooking. Bones may cause irregular cooking. Meat next to the tips of bones may overcook while meat positioned under a large bone such as a ham bone may be undercooked. Large amounts of fat absorb microwave energy and the meat next to these areas may get overcooked.

• New Larousse, 1983, Gastronomique—The World's Greatest Cookery Reference Book, Prosper Montague Publishing Group Ltd., Hamlyn, London.

QUESTIONS

1. Give the ICMR classification of food groups.
2. Define the following.
   (a) Mince (b) Bind (c) Fold (d) Dredging
3. Why do we cook food? What are limitations of it?
4. Classify different methods of cooking and explain any five methods in detail.
5. Define poaching. Bring out the advantages of it.
6. What is the best method of cooking rice? Why is it so?
7. Explain the different dry methods of cooking.
8. What is the principle of microwave cooking. Explain its construction and superiority over the traditional methods of cooking.
9. How is heat transferred in baking? What are foods normally cooked by baking?
10. Describe the different methods of cooking in which steam is used.
11. Give the advantages of pressure cooking.
12. Explain the methods in which air is used as medium of cooking.
13. Compare shallow fat frying and deep fat frying methods. Give suitable examples.
14. Name five preliminary methods of cooking. Discuss advantages and limitations giving suitable examples.
15. Give the principles of solar cooker. Enumerate the advantages.

PRACTICALS

1. Grouping of foods—Discussion on nutritive values.
2. Technique in measurements of foodstuff—Use of standard measuring cups and spoons—weight-volume relationships.
3. Survey locally available foods and identify.
4. Find edible and non-edible portions of food.
5. Give the nutritive value (Energy and Protein) per 100g of food, selecting from all the food groups.

Chapter 2

CEREALS AND CEREAL PRODUCTS

The cereal grains are seeds of the grass family. The word cereal is derived from ceres, the Roman Goddess of grain. The principal cereal crops are rice, wheat, maize or corn, jowar, ragi and bajra. The term cereal is not limited to these but also flours, meals, breads and alimentary pastes or pasta.

The ease with which grains can be produced and stored, together with the relatively low cost and nutritional contribution has resulted in widespread use of cereal foods. They are the staple foods in the diets of most population groups.

STRUCTURE

The overall structure of all cereal grains is basically similar differing from one cereal to another in detail. The percentage of endosperm, germ and bran of cereal are 83, 14½ and 2½ respectively.

Bran or pericarp: The outer layer, epidermis of the cereal consists of thin walled long rectangular cells. Next to the epidermis is the hypoderm of varying thickness. The inner most layer of pericarp tears during the ripening of the seed and in the mature grain they are represented by a layer of branching hypha-like cells called tube cells.

The seed coat or testa is a thin single or double layer. The inner layer of testa of wheat is often deeply pigmented which gives the grain its characteristic colour. Next to testa is a hyaline layer (nucellar tissue) which is colourless and devoid of any obvious cellular structure.

Aleurone cell layer: The endosperm is surrounded by one or more layers of cells known as aleurone. In wheat, the aleurone is a single layer of thick walled cubicle cells and constitutes 7% of grain weight. The cells contain about 20% each of protein, oil and mineral matter. The cells are also rich in nicotinic acid. The aleurone cells also contain tiny grains of phytic acid with some protein.

Endosperm: The endosperm itself consists of cells of various sizes, shapes and different composition. The endosperm cell consists mainly of starch and protein, the starch being in the form of spherical granules which are single granules or tightly packed together and embedded in a matrix of protein. The size and shape of the starch granule in the endosperm cells vary from one cereal to another.

Embryo: The germ or embryo consists of many parts. It is separated from endosperm by scutellum which has the function of mobilizing the stored food in the endosperm and transmitting them to the embryo when the grain germinates. The germ and scutellum are rich in protein and fat. Most of the B vitamins in the grain are present in the scutellum.
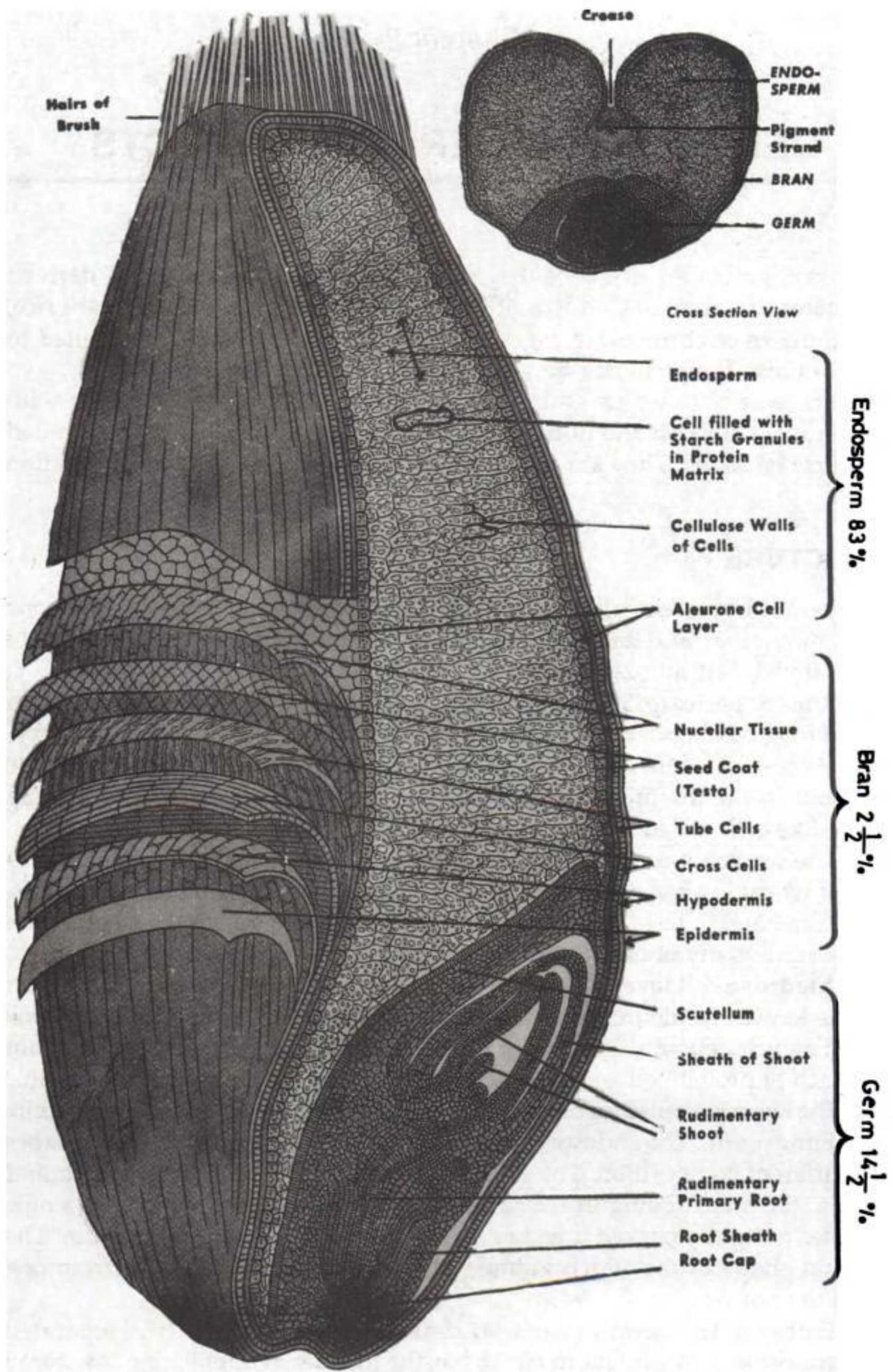
Figure 2-a: Longitudinal section of grain of wheat

Source: 'From wheat to flour', Wheat Institute, Chicago, Illinois.

Table 2.1: Nutritive value of cereals (per 100 g)

Food	Energy kcal.	Protein g.	Fat g.	Carbo-hydrates g.	Calcium mg.	Iron mg.	Caro-tene mcg.	Thiamin mg.	Ribo-flavin mg.	Niacin mg.
Bajra	361	11.6	5.0	67.5	42	8.0	132	0.33	0.25	2.3
Jowar	349	10.4	1.9	72.6	25	4.1	47	0.37	0.13	3.1
Maize, dry	342	11.1	3.6	66.2	10	2.3	90	0.42	0.10	1.8
Maize, tender	125	4.7	0.9	24.6	9	1.1	32	0.11	0.17	0.6
Ragi	328	7.3	1.3	72.0	344	3.9	42	0.42	0.19	1.1
Rice, parboiled, handpounded	349	8.5	0.6	77.4	10	2.8	9	0.27	0.12	4.0
Rice, parboiled, milled	346	6.4	0.4	79.0	9	1.0	–	0.21	0.05	3.8
Rice, raw, handpounded	346	7.5	1.0	76.7	10	3.2	2	0.21	0.16	3.9
Rice, raw, milled	345	6.8	0.5	78.2	10	0.7	0	0.06	0.06	1.9
Wheat flour (whole)	341	12.1	1.7	69.4	48	4.9	29	0.49	0.17	4.3
Wheat flour (refined)	348	11.0	0.9	73.9	23	2.7	25	0.12	0.07	2.4
Wheat bread (white)	245	7.8	0.7	51.9	11	1.1	–	0.07	–	0.7

Source: Gopalan C., B. V. Rama Sastri and S. C. Balasubramanian, 1991, Nutritive value of Indian foods, National Institute of Nutrition, ICMR, Hyderabad.
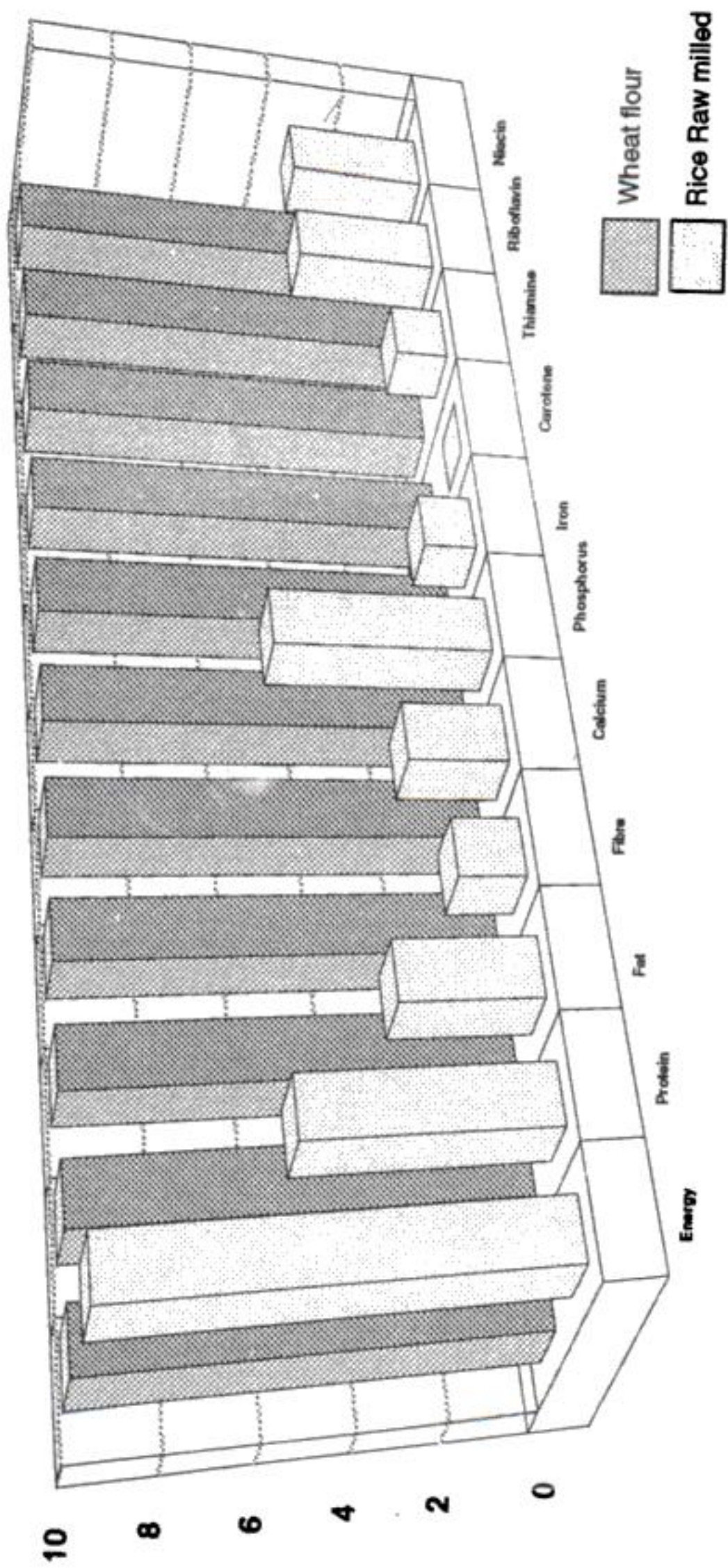
Figure 2-b: Comparison of nutritive value of wheat and rice
(For the sake of convenience all the values of wheat are taken as 10 and compared with the value of rice)

COMPOSITION AND NUTRITIVE VALUE

Nutritive value of different cereals is given in Table 2.1.

Energy: Cereals are the main source of energy, contributing 70-80% of the requirement. Hundred grams give more than 340 kcal of energy.

Carbohydrates: 80% of dry matter of cereals is carbohydrate. The two carbohydrates present are crude fibre and soluble carbohydrate. The fibre constituents are cellulose, hemicellulose and pentosans. Of the soluble carbohydrate, starch is the most important carbohydrate in all cereals. Small quantities of dextrin and sugars are also present. Free sugars present include simple sugars such as glucose and disaccharides like sucrose and maltose. Of all the cereals, whole wheat, ragi and bajra contain high amount of fibre.

Protein: The protein content of different cereals varies. Rice contains less amount of protein compared to other cereals. The protein content of different varieties of the same cereal also varies. Proteins are found in all the tissues of the cereal grain. Higher concentrations occur in the embryo, scutellum and aleurone layer than in the endosperm, pericarp and testa. Within the endosperm the concentration of protein increases from the centre to the periphery. The types of protein present in cereals are albumins, globulins, prolamines (gliadins) and glutelins. The proportion of these proteins differ in different cereals. The gliadins and glutelins are known as gluten proteins. The gluten has unique elasticity and flow properties which are used for baking bread and other products.

Cereals contain 6-12% protein, which is generally deficient in lysine. They provide more than 50% of protein requirement as they are consumed in large quantities. Among cereals, rice protein is of better quality than the others. Cereals, when consumed with pulses, the protein quality improves due to mutual supplementation. Cereals are deficient in lysine and rich in methionine. Pulses are deficient in methionine and rich in lysine. Hence there is improvement in protein quality of both proteins.

Lipids: Lipids are present to the extent of 1-2% in wheat and rice, and 3% in maize. More lipids are present in germ and bran than in other parts of the grain. Wheat germ contains lipids 6-11% and bran 3-5% and endosperm 0.8-1.5%. Lipid content of maize germ is 35% and the bran contains 1%. The lipids are mostly the triglycerides of palmitic, oleic and linoleic acid. Cereals also contain phospholipids and lecithin.

Considering the amount of cereal consumed it is estimated that fat present in cereals in our diets can meet more than 50% of our essential fatty acid requirement. Cereals together with pulses can nearly meet the essential fatty acid requirement of an adult.

Minerals: About 95% of minerals are the phosphates and sulphates of potassium, magnesium and calcium. A considerable part of phosphorus in cereals is present in the form of phytin. Phosphorus and calcium present in phytin are not available for absorption. Phytates present in cereals decrease the absorption of iron. Unrefined cereals contain more phytates than refined or polished cereals. On germination of the grains, the phytate content reduces due to enzymatic breakdown and iron availability is improved.

Some mineral elements like copper, zinc and manganese are also present in very small quantities in cereals.

Cereals are poor sources of calcium and iron particularly rice is a very poor source of these two elements. The content depends upon the extent of polishing. Ragi is a rich source of calcium and iron. Millets (ragi, bajra, jowar) are rich in minerals and fibre. The iron content of wheat is increased during milling where iron rollers are used.

Vitamins: Whole grain cereals are an important source of B vitamins in our diet. Since most of these vitamins are in the outer bran, refining or polishing the grains reduce B vitamin content. Parboiling which includes soaking in water and steaming of paddy results in seeping of vitamins present in outer layer into the grain. Hence milled and polished parboiled rice retains much of the B vitamins. Maida has less B vitamins than whole wheat flour.

Cereals do not contain either vitamin A or C except maize which contains small amount of carotenes. Oils from cereal grains are rich in vitamin E.

Nutritive value of wheat and rice is compared in the Figure 2-b.

Enzymes: Certain grains contain many enzymes and of these the amylases, proteases, lipases and oxido-reductases are of importance. Upon germination α amylase activity increases. The proteases are relatively more in the germ. The lipases of the cereals are responsible for the fatty acids appearing during storage of the cereals and their products.

SPECIFIC CEREALS

WHEAT

It belongs to the genus triticum and there are 30,000 species. The kernel of wheat is usually 1/8 - 1/4 inch long. In some kinds of wheat the tip of each kernel is covered by stiff hairs called the brush. Wheat grains are ovoid in shape, rounded in both ends. Along one side of the grain there is a crease, a folding of the aleurone and all covering layers.

Composition

Carbohydrate: Distribution of carbohydrate in wheat fraction is given in Table 2.2.

Table 2.2: Percentage distribution of carbohydrate in wheat

Carbohydrate	*Endosperm*	*Germ*	*Bran*
Starch	95.8	31.5	14.1
Sugar	1.5	36.4	7.6
Cellulose	0.3	16.8	35.2
Hemicellulose	2.4	15.3	43.1

Source: Shakuntala Manay, N, and M. Shadakshara Swamy, 1987, Foods, facts and principles, New Age International Publishers, New Delhi.

Proteins: Its content depends on the variety grown, climate and soil conditions. Proportion of different proteins in wheat grain as percentage of total protein are:

Albumin	–	5-10
Globulin	–	5-10
Prolamine	–	40-50
Glutelin	–	40-50

Wheat proteins are rich in glutamic acid and low in tryptophan. Glutamic acid and aspartic acid are present in the amide form as glutamine and asparagine. The high concentration of amide is important in determining the characteristic of the gluten. The bran and germ proteins have a higher content of essential amino acids than the inner endosperm proteins. Thus the biological value of endosperm proteins is much less than that of the whole wheat protein.

Milling of Wheat

Wheat is consumed mostly in the form of flour obtained by milling the grain while a small quantity is converted into breakfast foods such as wheat flakes and puffed wheat. Indian wheats are hard and the moisture content is usually 8-10%.

Table 2.3: Percentage composition of nutrients in different parts of wheat kernel

Nutrients	*Endosperm*	*Germ*	*Bran*
Protein	70-75	8	19
Thiamin	3	64	33
Riboflavin	32	26	42
Niacin	12	2	86
Pyridoxine	6	21	73
Pantothenic acid	43	7	50

Various steps are involved in making the flour. Figure 2-c gives the different steps.

The traditional procedure for milling wheat in India has been stone grinding to obtain whole wheat flour. In modern milling, the wheat is subjected to cleaning to remove various types of impurities together with damaged kernels.

- **Vibrating screen:** This removes bits of straw and other coarse materials and second screen removes foreign materials like seeds.
- **Aspirator:** It lifts off lighter impurities in the wheat. The stream of grain is directed across screens while air sucks off the dust and lighter particles.
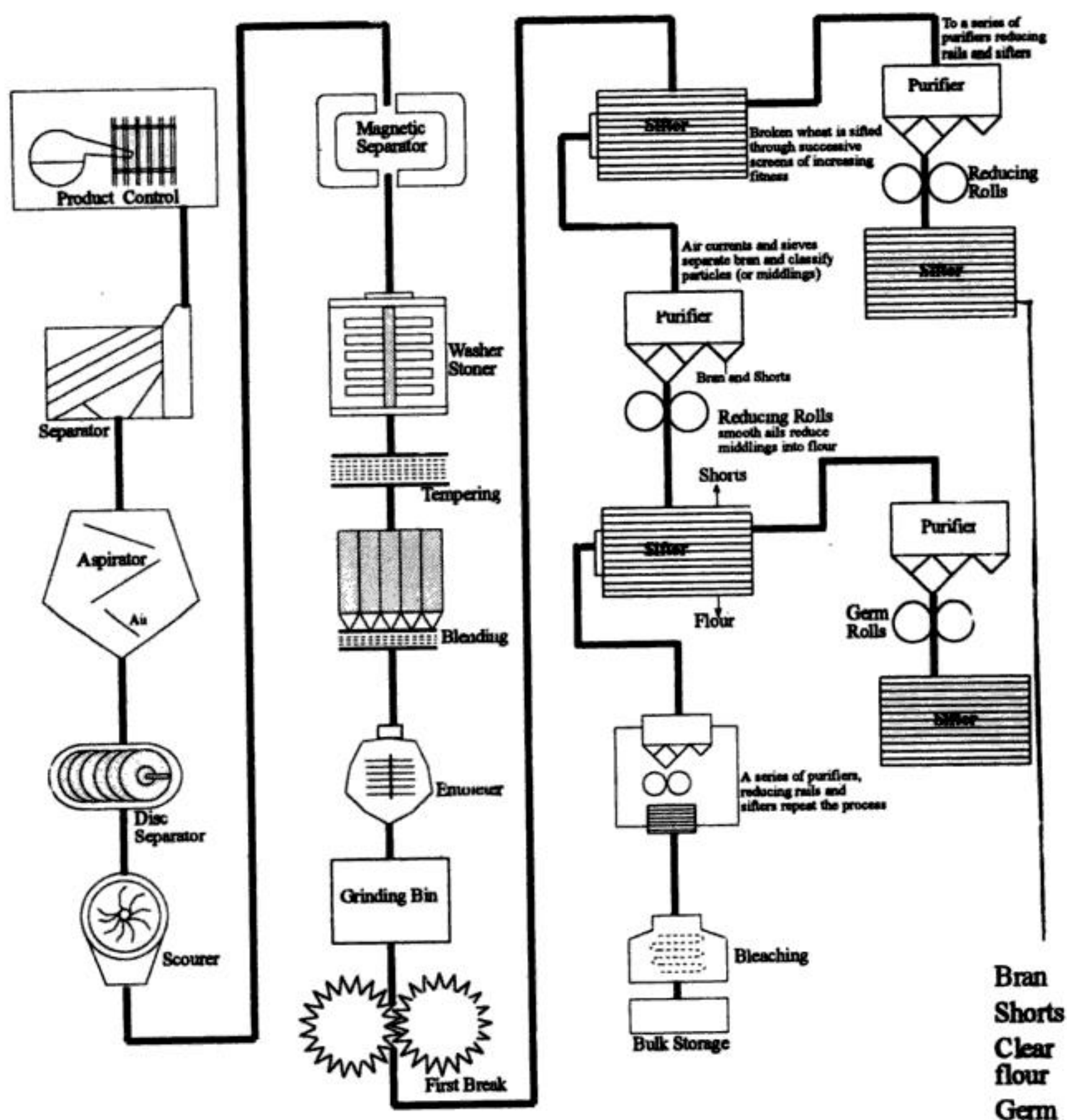
Figure 2-c: Milling of wheat

Source: From wheat to flour, 1965, Wheat Institute, Chicago, Illinois.

- **Disc separator:** After the aspirator it moves into a disc separator consisting of discs revolving on a horizontal axis. The surface of the discs indented to catch individual grains of wheat but reject larger or smaller material.
- **Scourer:** The wheat then moves into the scourer, a machine in which beaters attached to a central shaft throw the wheat violently against the surrounding drum, buffing each kernel and breaking off the kernel hairs.
- **Magnetic separator:** The stream of wheat next passes over a magnetic separator that pulls out iron and steel particles contaminated during harvesting.

- **Washer stoner:** High speed rotators spin the wheat in the water bath. Excess water is thrown out by centrifugal force. Stones drop to the bottom and are removed. Lighter material float off leaving only the clean wheat.
- **Tempering:** Wheat is tempered, before the start of grinding, the process in which moisture is added. Tempering aids in separation of the bran from the endosperm and helps to provide constant controlled amount of moisture and temperature throughout milling. The percentage of moisture, length of soaking, time and temperature are three important factors in tempering with different requirement in soft, medium and hard wheat. Dampened wheat is held in a bin for 8-24 hours. The outer layers of wheat tend to be brittle and tempering toughens the bran coat to permit more complete separation of endosperm. Within the kernel tempering also mellows or conditions the endosperm so that floury particles break more freely in milling.
- **Entoleter:** Discs revolving at high speed in the scourer aspirator hurl the wheat against finger like pins. The impact cracks down any unsound kernel which are rejected.
- **Grinding bin:** The "first break" rolls of a mill and are corrugated rather than smooth, break into coarse particles.
- **Sifter:** The broken particles of wheat and bran go into a box like sifter where they are shaken through a series of cloth or screens to separate larger from the smaller particles. Larger particles are shaken off from the top by leaving the final flour to shift towards the bottom.
- **Purifier:** The top fractions and particles of endosperm graded by size are carried to separate purifiers. In a purifier a controlled flow of air lifts off bran particles while cloth or screen separate and grade coarse fractions by size and qualities.
- **The down purifier:** Four or five additional break rolls with successively final corrugations and each followed by a sifter are usually used to rework the coarse stock from the sifter and reduce the wheat particles granular middlings as free from bran as possible. Germ particles being somewhat plastic will be flattened by a later passage through the smooth reduction rolls and tend to be easily separated.

The process is repeated over and over again. Sifters, purifiers reducing rolls until the maximum amount of flour is separated consisting of atleast 72% of wheat.

Products of Wheat

Whole wheat flour: It contains the finely ground bran, germ and endosperm of the whole kernel. Whole wheat products have a distinctive flavour and coarser texture than those made from white flour. Because of the higher fat content of the germ, whole wheat flour is more difficult to keep and sometimes becomes rancid in storage under poor conditions.

Iron fortified wheat flour has been successfully used to prevent iron de-

ficiency anaemia in some western countries. The study conducted at NIN (1998-99) revealed that ferrous sulphate is a cost effective and good source of iron in the process of wheat flour fortification.

Maida: The bran and germ are separated in making white flour or maida. Maida bakes more uniformly into a loaf of a greater volume and it is more bland in taste and more easily digested. It can be stored in an air-tight container in a refrigerator.

Semolina: It is coarsely ground endosperm and its chemical composition is similar to that of white flour. It is used in the manufacture of macaroni products. It is roasted before storing to save it from insects and worms.

Macaroni Products: These products are also called pasta or alimentary pastes. These products include macaroni, spaghetti, vermicelli and noodles. The main ingredient in the macaroni group of products is a special durum flour of high gluten content. Durum wheat is used because of its yellow-amber colour, nutty flavour and also because they hold their shape and firm texture when cooked. The starchy endosperm of wheat is coarsely ground into semolina which is made with water into a thick dough. The dough is placed in a cylinder, the lower end of which is fitted with a disc perforated with openings and as the dough is forced through the openings various shapes are formed. Macaroni is a tube form, spaghetti may be either tube or rod, vermicelli is a tiny rod and noodles are flat strips. Pasta products are also available in the shapes of shell and alphabets. Usually not less than 5.5 per cent by weight of egg solids are added to noodles.

All macaroni products are cooked gently in salted water to a standard called "al dente" i.e, to the tooth. They are quickly drained and not rinsed. Strands of macaroni should be tender, firm and distinct, not starchy, mushy or matted. Di sodium phosphate is added to cook macaroni faster and it increases alkalinity which enables the starch to gelatinise faster. Onions, celery, garlic, bay leaf are added as flavouring agents. Sometimes they are also enriched with B vitamins. They are used as soups, side dishes, salads and desserts or as main dishes. Popular dishes include vegetable noodles, kesari, upma and vermicelli payasam. Fried noodles are added to soups as thickening agent.

They can be prepared quickly and easily according to recipe or purchased in convenient precooked or ready to heat-and-eat form.

Different kinds of wheat are used for different purposes. For cakes and breads soft wheat, for macaroni hard wheat are used. In India Punjab wheat is used for making chapati and samba wheat is used for rava (upma) purpose. Maida is used for making sweets and snacks.

Malted Wheat: The process of malting consists of the following steps:

- Good quality grain is steeped in cold water for 36 hours in warm climate with two or three changes of water.
- The steeped grain is spread on wire mesh trays of 2-3" thickness which are kept in a stand. The germination is allowed to proceed for 3 days in a warm climate. During germination amylases and proteases are formed.
- Germinated grain is allowed to slow dry during which the amylases act

on starch, hydrolysing them. The drying should be at a low temperature to conserve as much of the enzyme activity as possible. During drying, the water soluble carbohydrates and nitrogen (peptones and peptides) increase. The characteristic malt flavour is developed. The malt is dried to a moisture content of about 13%.

Amylase Rich Food (ARF) is germinated cereal flours which are extremely rich in the enzyme alpha-amylase. Just tiny or catalytic amounts of any germinated cereal flour can instantly liquefy or reduce the dietary bulk of any viscous multi-mix gruel provided cereal flour is the main ingredient. The alpha-amylase cleaves the long carbohydrate chains in the cereal flour into shorter dextrins. Just half a flat teaspoon of any ARF can reduce even a very high total solid concentration of 45 g made up of 25 g flour, 15 g sweetener and 5 g oil cooked in 100 ml of water to a soupy consistency. This remarkable property makes it possible to offer the weaning child a low viscosity yet high energy dense preparation.

Malted cereal flour is inexpensive and can be made at home as well as commercially. Malt is used in brewing and in the preparation of malt extract for pharmaceutical purposes and in the preparation of malted milk powder.

Glutamic acid: It is derived from wheat. A familiar compound of glutamic acid is "mono sodium glutamate", a salt-like product generally available and used to bring out the flavour of other foods or seasonings.

Wheat bran: It increases the stool weight by increasing the water holding capacity of the bran. Wheat bran prevents constipation and may lower the risk of colon cancer.

Triticale: It is a hybrid cereal from a cross between wheat (Triticum) and rye (Secale). The hybrid cereal has the productivity and disease resistance of wheat with the vigour and hardiness of rye. The protein of triticale has a higher lysine content than that of wheat protein. The grains have 14-18 per cent protein as against 12-15 per cent in wheat. Chapatis are acceptable up to a 50 per cent level of incorporation of triticale flour.

PFA standards for cereals are given in Table 2.4.

RICE

Rice is a staple diet for more than half of the world's population. It is principally consumed in Asia.

Table 2.4: PFA standards for cereals

Standards	*Atta*	*Maida*	*Rava*
Moisture Maximum %	14.0	14.0	14.5
Total Ash Maximum %	2.0	1.0	1.0
Ash insoluble in dil. HCl %	0.15	0.1	0.1
Gluten minimum %	6.0	7.5	6.0
Alcoholic acidity as H_2SO_4 %	0.18	0.12	0.18

Composition

It is influenced by genetic and environmental factors. The germ, the pericarp and aleurone layers which are richer than endosperm in nutrients like protein, minerals and vitamins are separated from the grain during milling along with the husk.

Carbohydrate: The major carbohydrate of rice is starch which is 72-75%. The amylose content of starch varies according to the grain type. The longer grain and superior types containing upto 17.5% amylose while some coarse type are completely devoid of it. Glutinous rice consists almost entirely of amylopectin. Rice also contains some free sugars like glucose, sucrose, dextrin, fructose and raffinose. The fibre of rice is the hemi cellulose made up of pentoses, arabinose and xylose.

Protein: The protein content of rice is 7%. It is much lower than that of the wheat. Glutelin which is also known as oryzenin is the principal protein of rice. Rice also contains small quantities of albumin, globulin and prolamines. The proteins of polished rice have a lower biological value but a higher digestibility than those of rice bran and rice polishing. Parboiling has no effect on the biological value or digestibility of the proteins. The nutritive value of rice protein is of high order being superior to that of the wheat and other cereal products. The rice proteins are more rich in arginine compared to other cereal proteins. Rice is deficient in lysine and threonine. The biological value of rice protein is 80 whereas wheat protein has 66 and maize protein has 50.

Minerals: In its mineral content, rice resembles other cereals. Most of the minerals present in the rice are located in the pericarp and germ. Polished rice is poor in calcium and iron. Coloured types of rice contain more iron than the white rice. The phosphorus content is high, about 4% of which is present as phyticacid. Rice also contains some trace elements.

Enzymes: Rice contains amylases, proteases, lipases, oxidases, peroxidases and phenolases. On storage the oxidase activity of rice remains constant but the amylase, lipase, peroxidase activities decrease. The activity of the alpha amylase in fresh rice is probably responsible for its sticky consistency after cooking. This enzyme gets inactivated during storage and cooked grains get separated easily.

Pigments: Coloured rice contains anthocyanins and carotenoids.

GOLDEN RICE

Nutritional genomics has been applied to rice for the development of golden rice. Golden rice has enhanced β-carotene, iron and proteins particularly amino acid lysine. Golden rice would reduce the incidence of malnutrition globally.

Milling

Before milling paddy is cleaned to remove small and large, heavy impurities. In dehulling and milling coarse outer layer of bran and germ are removed. Paddy on milling yields hulls 20%, bran 8%, polishing 2% and rice 70%.

Paddy is milled in India either by home pounding or in mechanised rice mills. In home pounding there are more broken rice. Storage life is short as the fat in the bran develops rancidity.

The process of milling involves the following steps.

- Rice is passed through two stone or rubber discs rotating at different speeds and by shearing action on the grain, the hull is pulled away. The whole kernel from which the hulls have been removed is known as brown rice.
- This is then milled in a machine called pearler to remove coarse outer layers of bran and germ by a process of rubbing, resulting in unpolished milled rice. Some amount of breakage of rice occurs in this milling.
- Unpolished rice is liable to develop rancidity and so it is next polished in a brush machine which removes the aleurone layer and yields "polished rice".
- Sometimes the polished rice is further treated in a device known as trumbol to give a coating of sugar and talc to produce a brighter shine on the grains.
- Rice is separated from the broken kernels. Large kernels are called as second heads, medium ones are called screenings, smallest ones are called the brewers rice.

Most varieties of coarse rice are not highly polished. As the Indian Government regulations the extent of polishing should not exceed 5%. If rice is milled beyond 10% then most of the thiamin is lost. The percentage of losses of different nutrients during milling are protein 15%, fat 82%, thiamin 85%, riboflavin 70%, pyridoxine (vitamin B6) 50%.

The degree of milling determines the amounts of nutrients removed. Losses during milling can be compensated by the following processes.

- By under-milling or unpolishing rice the loss of nutrients can be reduced. Rice that is under-milled do not have the customary white lustre and they are more subject to insect infestation and flavour deterioration than white rice is.
- A second method is that of increasing vitamin retention by processing the rough rice prior to milling. This is done by parboiling which is commercially known as converted rice.
- Another means of remedying the losses occurring in the milling of rice is the artificial enrichment of the grain. A premix has been developed in which the rice is wetted with a solution of thiamin and niacin, then dried. A second coating of iron pyro phosphate is distributed on the rice. The rice premix is highly resistant to washing, cooking and storage losses.

Figure 2-d shows losses of thiamin in milling.

Parboiling

It originated in India. Half of India's rice crop is parboiled. Parboiling is particularly good in the case of coarse and medium rice of soft structure because such rices suffer excessive breakage when milled raw. Parboiling involves soaking paddy in water for a short time followed by heating once or twice in steam and drying before milling.

Conventional process: This consists of the following steps:

1. Steeping paddy in cold water for 2 or 3 days in large cement tanks.
2. Steaming of the soaked paddy for 5-10 minutes and
3. Drying in the sun.
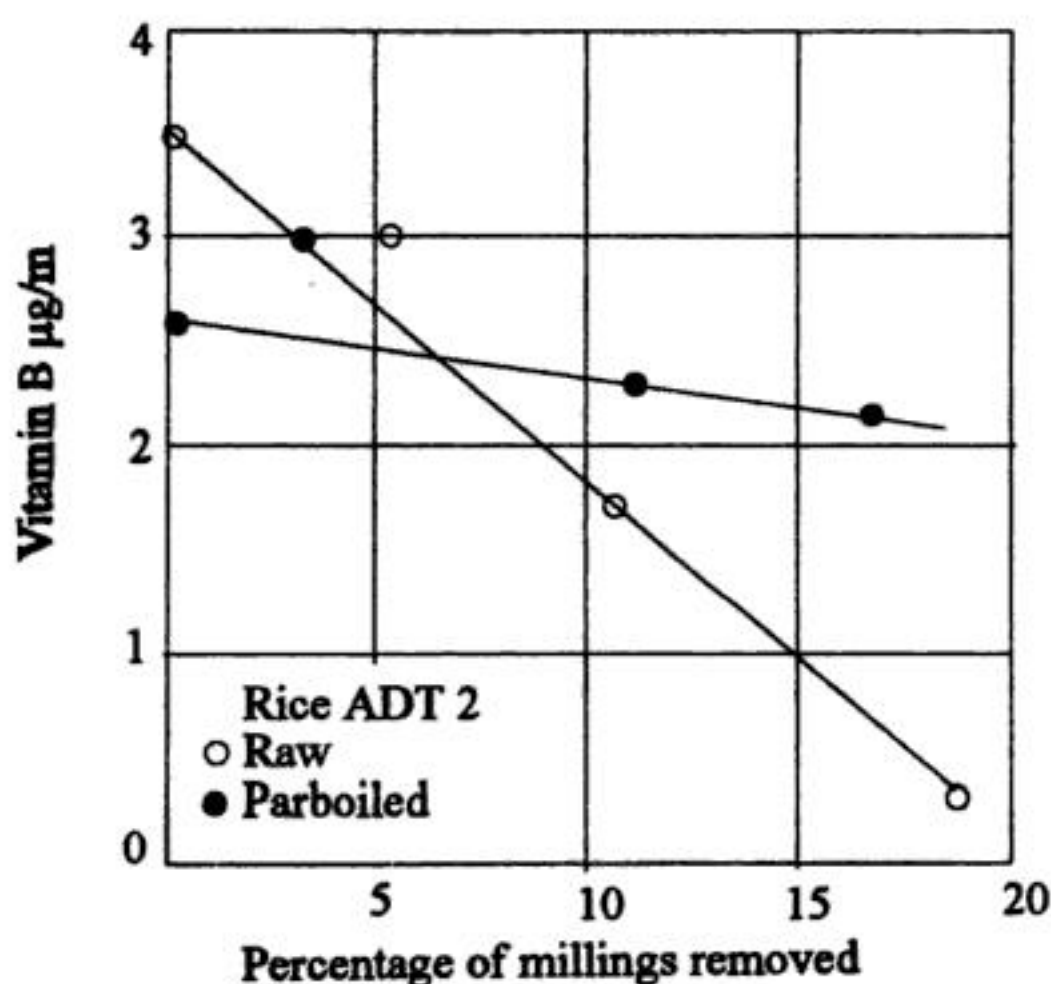
Figure 2-d: The effect of milling in the raw and parboiled states on thiamin content of rice.

Source: Passmore R., M.A. Eastwood, 1987, Davidson and Passmore human nutrition and dietetics, English Language Book Society, Churchill Livingstone.

During soaking of paddy in cold water for 2 or 3 days, fermentation sets in and off flavour develops in the grain. The moulds present in the grain also grow and may produce toxic metabolites. For example aflatoxin may be produced from *aspergillus flavus.*

Hot soaking process: The hot soaking process, developed at the Central Food Technological Research Institute, Mysore consists of the following steps:

1. Soaking of paddy in water at 65-70°C for 3-4 hours.
2. Draining of water and steaming of soaked paddy in the same vessel for 5-10 minutes and
3. Drying of the paddy in the sun or in mechanical driers.

Advantages of parboiling:

- Dehusking of parboiled rice is easy.
- Grain becomes tougher resulting in reduced losses during milling.
- Milled parboiled rice has greater resistance to insects and fungus.
- Loss of nutrients due to the removal of husk and bran in milling are decreased. During harvesting the vitamin and mineral present in hull (outer covering of the paddy) and bran coat are dissolved and seeped into the endosperm. Part of the scutellum and germ which are rich in B vitamins get fixed to the grain and hence losses of B vitamins are less.
- Losses of water soluble nutrients due to washing of rice is less in parboiled rice compared to raw rice.
- Parboiling improves digestibility and Protein Efficiency Ratio is higher compared to raw rice.
- Parboiled rice will not turn into glutenous mass when cooked.
- Parboiled rice swells more when cooked to the desired softness.
- Parboiling stabilises the oil content of the bran.

Disadvantages of parboiling:

- Sometimes it has an unpleasant smell and hence not preferred.
- Colour changes may occur during parboiling.

The retention of vitamins and minerals in various forms of rice is given in Table 2.5.

Table 2.5: Retention of vitamins and minerals in various forms of rice

Nutrient	*Brown rice*	*Polished rice*	*Hand pounded rice*	*Parboiled rice*
	Quantity μg/100g	*Expressed as percentage of the quantity present in brown rice*		
Thiamin	320	15	66	72
Riboflavin	156	35	87	66
Niacin	4600	37	85	83
Folic acid	36	22	60	30

Source: Achaya, K.T., 1998, Food processing and nutrition from Textbook of Human Nutrition, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

Rice Products

Rice starch: Rice starch granules are quite small and are embedded in a protein matrix. To separate them from protein, broken rice is steeped for 24 hours in 5 times its weights of 0.3% caustic soda. The caustic soda treated granules are washed, dried and ground into flour. The flour is then mixed with about

ten times its weight of caustic soda solution. This removes gluten. After 24 hours, the starch that settles down is removed, washed and dried. Rice starch is used in puddings, ice-creams and custard powder. It forms a tender opaque gel.

Rice bran: Breakage of the white rice kernel during milling also results in small fragments of the endosperm becoming part of the bran fraction. These broken fragments are primarily starch and normally contains 10-12% of bran.

If the bran is subjected to a short term high temperature after milling, the lipase activity is destroyed and stabilized bran of edible grade is produced. Bran produced from parboiled rice is already stable and does not require any further stabilization treatment.

Stabilized or parboiled food grade rice bran is normally finely granulated light tan in colour and it has bland flavour and can be used in preparation like bread, snacks, cookies, and biscuits. In addition rice bran is a very rich source of dietary fibre so it is an effective stool bulking agent.

Table 2.6: Nutritive value of rice bran per 100 g

Nutrient	*Amount*	*Nutrient*	*Amount*
Energy kcal	393.0	Riboflavin mg	0.48
Protein g	13.5	Niacin mg	29.8
Carbohydrate g	48.4	Calcium mg	67.0
Fat g	16.2	Iron mg	35.0
Thiamin mg	2.7	Fibre g	4.3

Rice bran oil: Central Food Technological Research Institute, Mysore, has developed low cost chemical methods to extract edible grade oil from rice bran. National Institute of Nutrition, Hyderabad has certified that this oil is toxicologically safe for human consumption. This oil is rich in Vitamin E which gives oxidative stability to the oil. In addition it has higher cholestrol lowering effect than other oils. The keeping quality of this oil is high when compared to other oils. Foods deep fried in rice bran oil showed that this oil is less absorbed or consumed in fried foods when compared to food fried in ground nut oil.

Parched rice products: About 4-5% of total supplies of rice in India is converted into rice products—parched rice, parched paddy and rice flakes.

Parched rice: Parboiled rice is soaked in salt water to increase the moisture to about 20 per cent. Parched rice is prepared by throwing rice in sand heated to a high temperature in iron or earthen pan. On stirring rice begins to crackle and swell. Then the contents of the pan are removed and sieved to separate the parched rice from sand. Parboiled rice is used in making parched rice. Parched rice is a crisp product with a greyish to brilliant white colour and is sold either salted or unsalted. It is eaten as such or mixed with buttermilk and then consumed.

Parched paddy or puffed rice: Sun ripe paddy is filled in earthen jars

and is moistened with hot water. After 2-3 minutes the water is decanted and the jars are then kept in an inverted position for 8-10 hours. The paddy is exposed to sun for a short time and then parched in hot sand 190-210°C for 40-45 sec. During parching the grains swell and burst into soft white product. The parched grains are sieved to remove sand and winnowed to separate the husk.

Flaked rice: Flaked rice is made from parboiled rice. Paddy is soaked in water for 2-3 days to soften the kernel followed by boiling water for a few minutes and the water is drained off. The paddy is heated in a shallow earthen vessel or iron pan till the husks break open. It is pounded by an iron pestle or use iron roller which flattens the kernel and removes the husk. The husk is separated by winnowing. Flaked rice is thin and papery and of white colour.

Advantages of parched rice products:

- Easily digestible and hence good for children and old people.
- Readily available to eat due to faster cooking.
- It adds variety in the diet.
- Since iron pans are used, iron content is increased.
- Improves flavour and texture.

Aromatic rice: Aromatic rice varieties contain acetyl 1-1 pyrroline as the major aroma principle while cooking. These are characteristic of the rice variety. Non-aromatic rice varieties can be flavoured by adding one or two fresh leaves of *Pandanus latifolius* while cooking as they contain 2-acetyl 1-1 pyrrole.

MILLETS

These are hardy plants capable of growing in areas where there is low rain fall and poor irrigation facilities. Apart from maize and sorghum, the major millet crops of India are pearl millet called bajra and finger millet known as ragi.

MAIZE OR CORN

In India maize is consumed in the form of boiled or roasted as pop corn. In countries like South America, Central America and Africa, it is converted into food products by grinding, alkali processing, boiling, cooking and fermentation.

Nutritive Value

Maize contains around 11% of protein. Maize protein is deficient in amino acids like tryptophan and lysine. New varieties with high lysine are being produced in countries like America. Maize is a good source of carotene. It also contains thiamine and folic acid in appreciable amounts.

Maize is like any other cereal, rich in calories and is used in supplementary nutrition programmes and Integrated Child Development Services programmes to feed malnourished children.

According to the studies conducted at National Institute of Nutrition, Hyderabad, 17-56% of aflatoxin is reduced in maize by cooking.

Processing

There are three major processes utilized in the production of maize for food usage:

Dry milling: Grinding of the whole grain stone or roller mill to produce flour or meal is a simple method used worldwide when the ground products are to be consumed shortly after processing. The stability of such products is limited owing to the presence of crushed germ in the flour. Oil from broken germ cells is easily oxidised to produce rancid odour and flavour.

The large as well as small grits are used in the production of corn flakes and breakfast cereal. Dry milled germ can be pressed or solvent extracted to recover the valuable oil. The major advantage of maize dry milling are the lower capital costs as compared to wet milling.

Wet milling: In developed countries like USA, the major utilisation has been wet milling. The two most important products of wet milling are high fructose corn syrup and ethanol.

Alkali Processing: In this, the maize is mixed with water and lime and cooked at 90°C for 50 minutes. The cooked maize is then steeped for 14 hours before being washed with fresh water to remove residual alkali and other waste material from maize. The washed maize is milled to a gritty textured product called "masa". This is rolled into flat cakes and baked in an oven for 1-2 minutes to produce the traditional tortilla. Masa can also be deep fried to produce tortilla chips or maize chips or it can be dried and finally milled to produce a mass flour.

Products of maize

Degerminated flour: This consists mostly of the endosperm and has low content of B vitamins. It is used by brewers as a starch medium for the action of barley malt in the preparation of wort for the production of beer.

Corn germ oil: It can be extracted by solvent extraction. Maize oil has become a highly desired vegetable oil owing to its relatively high level of linolenic fatty acid and its excellent flavour. The fat content of maize is 3.6% and oil extracted from it can be refined to produce a high quality vegetable oil for cooking or food use.

Popcorn: The popping of corn is a method of starch cookery. As the kernels of popcorn are heated, the water vapour within them expands, increasing the pressure until it is sufficient to make the kernels explode or "pop". Desirable qualities in popcorn are good flavour, tenderness, the absence of objectionable hulls and high popping expansion. To make pop corn hard corneous endosperm is desirable. 13.5% of moisture is recommended for best popping expansion. Popping can be done with or without fat.

Corn starch: It is most widely used. It is made by a process of wet milling in which the hull and germ are removed, the corn ground and mixed with water.

The semi liquid material is separated by passing it over sieves or centrifuging it. The starch settles out while most of the protein remains suspended. The starch is then washed, dried, powdered. Corn starch is widely used because it is inexpensive, lacks characteristic flavour and cooks to a smooth and almost clear paste in water or other clear liquid and superior to wheat flour or potato starch.

JOWAR

Jowar or sorghum millet is grown in Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Gujarat, Uttar Pradesh and Tamil Nadu. It is used as roti or bhakri.

Nutritive value: Compared to rice, jowar is richer in protein but the quality is not as good as rice protein. Lysine, methionine and cystine are present in low amounts in jowar. Some varieties of jowar contain excessive amounts of amino acid called leucine. The resulting imbalance between leucine and isoleucine interfere with conversion of tryptophan to niacin causing deficiency of niacin.

Since cereal and legume proteins are complementary to each other jowar and any legume in the ratio of 70:30 will give better nutritional value.

Jowar is rich in carbohydrates and B-complex vitamins. It is poor in vitamin A and rich in dietary fibre.

Processing: Pearling involves wet milling, where top layers bearing the colour and fibre are removed by abrasion. Polished grain with low fibre content results in loss of nearly 20% protein, 50% minerals and 33% thiamine. Milling removes the proteins in the bran and the germ, which are nutritionally superior to the protein present elsewhere in the grain.

Some jowar is consumed as parched. According to the research conducted at Andhra Pradesh Agricultural University, Rajendra Nagar, Hyderabad, popping and flaking of jowar improves the starch digestibility five times but reduces the protein digestibility in flakes. Whole jowar recipes significantly lowered plasma glucose levels than dehulled jowar recipes in non-insulin dependent diabetic persons.

Many infant foods are manufactured commercially using malted jowar.

RAGI

Ragi is also known as finger millet. It constitutes a little over 25% of the food grains grown in India. It is widely consumed practically without any refining by the poorer section of the population.

Nutritionally it is almost as good as or better than wheat or rice. The major proteins of ragi are prolamins and glutelins and they appear to be adequate in all the essential amino acids. Ragi is rich in minerals especially calcium. It is also rich in fibre. It is also rich in phytate and tannin and hence interfere with mineral availability. It contains B-vitamins but is poor in B_2.

Recent work carried out at CFTRI, Mysore has shown refining the grains can upgrade the quality and adds variety and taste.

Milling: Ragi can be milled by wet conditioning. It can be steamed followed by milling in a hammer or plate mill or a roller flour mill.

Malting: Compared to other millets, ragi is most suitable, from the standpoint of product quality and enzyme release for malting. The malted ragi flour can be used along with germinated green gram flour to formulate a high calorie-dense weaning food having excellent nutritional qualities. Ragi flour can be used with milk beverages.

Parboiling of ragi helps in the quality of ragi dumpling by eliminating its slimy texture. Flour from puffed ragi has good flavour and can be used in snacks and supplementary foods.

In south India ragi is used as gruel, dumpling, roti, dosa or porridge.

BAJRA

Among millets, bajra is the predominant crop in India. It has the same quantity of protein as wheat. The protein contains a high proportion of prolamine followed by the globulin and albumins. Among the amino acids tryptophan content is high and lysine is too low. Bajra is rich in iron, thiamin, riboflavin and niacin.

Pearling of bajra to about 8% polish, leaves most of the germs intact and the nutritive value is not seriously affected. Pearling improves appearance and taste of the products.

It is dehusked and cooked in the same way as rice. Flour is made into bhakri. The grain is sometimes eaten after it is parched, the product being similar to popcorn. The grain is also suitable for the preparation of malt.

Storage of cereals

Most cereals and cereal products have such a low moisture content that little difficulty is encountered in the prevention of growth of microorganisms as long as the foods are kept dry. Such materials are stored in bulk or in containers so as to keep out vermin, especially insects and rodents.

As a result of infestation, a part of the grain is eaten away by insects and the taste, flavour and hygienic quality is affected. The nutritive value particularly PER of proteins and B-vitamins are affected. Pyrethrin and malathion are used to prevent infestation. Volatile oils from Mentha Spicata (mint) can be painted on the containers walls or can directly mixed with seeds for short term storage. Drying the grains in the sun to an optimal moisture content reduces damage by fungi. The storage bins should be made rodent proof.

WHOLE GRAINS AS FUNCTIONAL FOODS

- Antioxidants delay degenerative diseases
- Ferulic acid is anticancerous
- Phytic acid protects intestinal epithelium
- Insoluble fibre prevents constipation
- Enzyme blockers control diabetes due to delayed absorption.

CEREAL COOKERY

CEREAL PROTEIN – GLUTEN

Although all cereals are more or less similar in protein content the unique presence of glutelin and gliadin in the wheat makes it suitable for certain recipes. Glutenin or glutelin is the protein which gives toughness and rubberiness to gluten. Gliadin gives elasticity. Glutenin is a much larger molecule than gliadin. During the mixing of a dough the long strands of glutenin evidently become aligned in the direction of mixing and associated with gliadin molecules to form a strong elastic uniform film that envelops the starch granules in the dough. In the presence of water and with mechanical agitation the protein fraction forms a tough elastic complex termed gluten which is capable of retaining gases and by doing so a leavened product is obtained. Due to its elastic property, the dough can be rolled to prepare chapati or puri. Cereals other than wheat cannot form a large light loaf and cannot be rolled since gluten is not developed.

During dough formation, the disulphide (S—S) bonds are cleaved to sulpha hydryl bonds (—SH) by the reducing agent present in flour. In addition to disulphide bonds other types of bonding also make important contributions to dough development.

Gluten from strong flour is more perfect colloidal gel, as shown by its greater hydration capacity than gluten from a soft flour. Baking quality of flour depends on both the quantity and quality of gluten that can be formed from it.

The insoluble protein gluten can be separated readily from flour by adding water to form a stiff dough and then kneading in water to wash away other constituents, largely starch. The wet gluten is a cohesive, elastic mass that expands greatly on baking to form a light porous ball. Baked gluten contains about 85% protein, 8% lipids and variable amounts of starch depending on the thoroughness of washing. Baking the gluten shows that it expands greatly as the steam within it expands and that it coagulates when heated to form the structure of the baked product.

Factors that affect the gluten formation

Mechanical action: If the dough is undermixed, enough gluten is not developed to retain the gas well. With the result the loaf is heavy and poor in volume. Over-kneading declines the elasticity of gluten and the dough becomes sticky and the volume of the loaf poor. In making chapatis, too little or too much gluten results in poor quality.

Proteolytic enzymes: These are a group of enzymes present in wheat flour which catalyse the hydrolysis of proteins. They are also present in malted flour and yeast. Since the strength of the gluten depends on the intact protein, any reaction which hydrolyses part of the protein reduces the amount of gluten. If too much of these proteolytic enzymes are present, too much hydrolysis occurs and the dough becomes sticky, difficult to machine in the mixers and

yields bread of poor volume. Some protease activity is desirable, since it improves the glutens. Doughs of low proteolytic activity are tough and inelastic. It does not machine well and it also produces loaves of poor volume since the dough will not stretch around the gas bubbles. The quantity of proteolytic enzymes must be balanced so that enough hydrolysis occurs to produce an elastic gluten but not so much that the gluten is sticky.

Oxidising agents: Potassium bromate, potassium iodate are dough conditioners. Chlorine, chlorine dioxide and nitrosyl chloride, bleach, mature and improve the flour.

If an oxidising agent is added either to flour or to gluten the strength of gluten is increased. If large amounts are added gluten becomes tough with little elasticity. Reducing agents have the opposite effect. They reduce the strength of gluten making it more extensible and sticky.

Fermentation, oxidation, kneading change the bonding of the protein molecule. Oxidation affects the sulfhydryl group and increases the number of S-S links. If the S-S links are formed between the poly peptide chains, they will hold the molecule together more firmly and increases its strength. The amount of oxidation is critical and although the amount of oxidising agents needed is small, sufficient must be present to yield gluten strong enough to retain the gas formed but not so tough that it will be unable to stretch around the gas bubbles.

Other factors: Raw milk decreases the proteolytic enzymes and makes gluten sticky. Heating the milk to 82.2°C for 30 minutes has no detrimental effect on gluten strength. Milk should be scalded before use in a dough.

In general, calcium salts present in the hard water tend to increase the elasticity of gluten. NaCl likewise affects gluten. Acids also alter gluten strength. Too much of vinegar diminishes gas retention. Fats in small amounts increase the ability of dough to retain gas.

CEREAL STARCH

Starch is the main carbohydrate in cereals. All sources of starch consists of linear polymers of glucose which are tightly coiled in the form of granules. These have a characteristic shape and size depending upon the plant from which they are derived. Table 2.7 gives characteristics of different starch granules.

Two different types of chains may be distinguished in a starch molecule. The linear is termed amylose and the branched amylopectin. Amylose is soluble in water. One type of starch differs from another both in the length of amylose and amylopectic chains and in the proportion of each type of starch chains. The gelling ability of a starch depends upon the amylose content and a high amylopectin levels lower the ability of the starch to form a satisfactory gel. Table 2.8 gives amylose percentage of different cereals.

and the size of the particles diminishes. Increasing water molecules begin to penetrate freely between the starch molecules when their kinetic energy becomes great enough to overcome the attraction between starch molecules. Two starch molecules which were originally bound together are now two starch molecules with water in between. The sticking together of granules is the result of molecules from adjacent granules becoming attracted and enmeshed in one and other. The changes brought about by hot water on starch are irreversible.
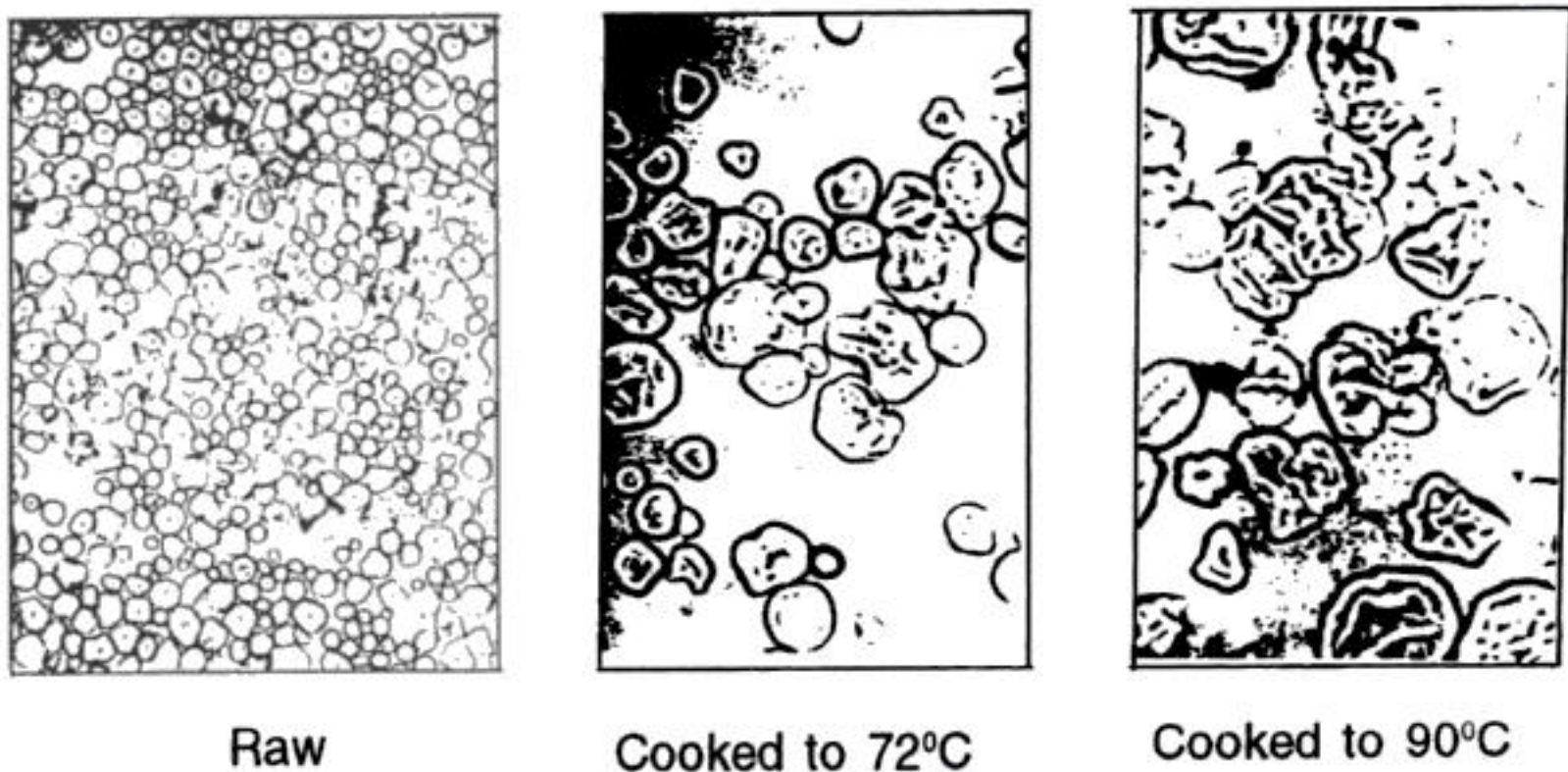
Figure 2-e: Microscopic examination of raw and cooked corn starch

Source: Bennion M., 1994, Introductory foods, Prentice Hall Inc.

Gelatinisation Temperature: A starch mixture will start to thicken somewhere between 74-88°C but complete gelatinisation will not occur until the mixture is close to or at the boiling point. This will vary with the type of starch and size of the grain.

Larger grains swell at a lower temperature. gelatinisation is complete for starches such as potato at a lower temperature because of the larger size of the granules. In any case, swelling is usually complete at a temperature of 88°C to 92°C. Depending on the variety and storage conditions gelatinisations temperature vary.

The increase in the viscosity of the heated starch mixture is caused by the action of the enlarged starch granules bumping against each other, trapping the water and inhibiting its free flow. Once a starch mixture has reached the temperature at which gelatinisation takes place, the mixture need only be held at that temperature until the flavour of the uncooked starch has disappeared.

Completely gelatinised starch should not be stirred unless necessary since the swollen granules are easily broken. The broken grains and fragments will thin out of the mixture. As the cooked starch mixture cools there is a marked increase in stiffness of the gel formed. This is due to the decrease in kinetic energy which keeps the molecules from reassociating.

Bread

The percentage of different ingredients for bread making is given below.

Ingredients	*Percentage*	*Ingredients*	*Percentage*
Flour	100	Water	60-65
Non fat dry milk	4	Yeast, compressed	2
Sugar	6-8	Salt	2
Shortening	3-4		

Procedure: The two methods of dough development is given in the schematic diagram 2-g.

Straight dough method	Sponge system
All the ingredients are mixed together and allowed to rise ↓ Temperature is maintained at 27°C ↓ Kneading by hand or mechanically to remove gas. (knock back) Allowed to rise again, till the bulk is doubled. ↓ The dough is allowed to prove at a 38-48°C for 45-60 minutes and baked for 30 minutes.	Mixed half the amount of flour with water, yeast and other ingredients ↓ Allowed to ferment The first dough is formed ↓ Mixing of the remaining ingredients to the dough and allow it ferment.

Figure 2-g: Dough development in straight dough method and sponge system.

The role of ingredients in making bread

Flour: Gluten makes the dough easy to handle and permit a large expansion during fermentation and in early stages of baking. Glutenin controls the elasticity of the gluten and the time required for dough development while gliadin proteins are responsible for loaf volume.

Starch granules becomes closely associated with gluten during dough making and this prevents an excessively cohesive structure. If the starch is damaged during milling, it absorbs water, thus competing with gluten proteins for available water. Flour amylase attacks the damaged starch. It is also essential to have damaged starch in adequate amount, so as to supply sugar during fermentation. Excess starch damages the bread and loaf volume decreases and bread is less attractive in colour.

the egg protein which is in a network of protein and capable of maintaining the increased volume of the mixture. The lecithin in egg yolk acts as an emulsifying agent of the fat in the batter. It also adds colour and flavour to the baked products.

Leavening agents: The leavening agent in cake is baking powder which has sodium bicarbonate and acid. Baking powder in the moist batter at the oven temperature forms carbon dioxide and causes leavening. Air incorporated to the flour mixture through creaming of fat and sugar also acts as leavening agent.

Table 2.9: Possible causes of loss of quality in cakes

Problem	*Possible Cause*
Too dark a crust	Too hot an oven; use of fructose or honey; position too close to top or bottom of the oven.
Fallen centre	Too much sugar; too much fat; too much baking powder, inadequate baking; too cool an oven; door opened during baking.
Peaked or humped	Too much flour; too little sugar, fat or milk; too hot an oven; over stirring (too much gluten developed) too deep a pan.
Poor volume	Not enough leavening agent; too cool an oven; too much fat or liquid.
Large cells and tunnels	Too much baking powder; excessive mixing.
Dry tough crumb	Too much flour; too much egg; too little fat; too little sugar; too little liquid.
Sticky sugary crust	Too much sugar.
Over flowing pan	Too small a pan; too much sugar; too much baking powder

Table 2.10: Nutritive value of baked wheat products

	kcal per 100 g	*Moisture %*	*Starch %*	*Sugar %*	*Protein %*	*Fat %*
Bread						
White bread	270	36	50	–	8.5	3.5
Brown bread	240	36	45	–	10.0	3.0
Biscuits						
Marie/Arrowroot	478	8	40	24	6	22
Ginger	533	8	37	25	5	25
Glucose	443	8	41	32	4	15
Salted Snacks	518	8	48	10	4	30
Wafers	418	8	61	15	4	10
Cakes						
Plain	470	17	21	25	7	30
Fruit	380	18	36	21	5	20
Sponge	300	30	22	33	9	6

Source: Achaya, K.T., 1998 "Food processing and nutrition" Textbook of human nutrition edited by Bamji et al. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

- Cereals are used as thickening agent, e.g., corn flour in custards, rice flour in pulusu, veronicelli in payasam, corn flour in white sauce, macaroni in soups.
- Cereals are used as coating agent, e.g., maida paste in cutlets or bread crumbs in cutlets.
- Cereals are used as beverage, e.g., malted beverage.
- Cereals used as desserts, e.g., rice kheer, wheat halwa.
- Cereals are used in making easy to cook products like macaroni, corn flakes and rice flakes.
- Cereals are used as covering for stuffing samosas, puran poli.
- Fermented foods made from cereals are used as breakfast foods or snacks, e.g., idli, dhokla.

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- Kaur Hardeep and Usha Bajwa, Effect of heat refreshing on quality of stored chapatis containing butter milk, J. Food. Sci. Technol., 2000, *37*, 2000.

QUESTIONS

1. Draw the structure of wheat grain and name the components. Explain the function of each component.
2. Compare the nutritive value of rice and wheat.
3. How is gluten formed and explain its role in cereal cookery.
4. Explain the factors affecting gluten.
5. Write short notes on
   (a) macaroni products
   (b) Bread making
6. What are the different methods of parboiling rice? Explain the advantages and limitations.
7. Give the recipe for making bread and explain the role of different ingredients.
8. What is 'fermentation'? Discuss the advantages of fermentation. Give examples for fermented foods.
9. Explain the effect of moist and dry heat on starch.
10. How does lump formation occur in starch? How do you prevent it.
11. Define and explain the terms gelatinisation, dextrinisation, retrogradation and syneresis.

Table 3.2: Nutritive value of the pulses (per 100 g.)

Food	*Energy* *kcal.*	*Protein* *g.*	*Fat* *g.*	*Carbo-hydrates* *g.*	*Calcium* *mg.*	*Iron* *mg.*	*Caro-tene* *mcg.*	*Thiamin* *mg.*	*Riboflavin* *mg.*	*Niacin* *mg.*
Bengal gram whole	360	17.1	5.3	60.9	202	4.6	189	0.30	0.15	2.9
Bengal gram dhal	372	20.8	5.6	59.8	56	5.3	129	0.48	0.18	2.4
Bengal gram roasted	369	22.5	5.2	58.1	58	9.5	113	0.20	–	1.3
Black gram dhal	347	24.0	1.4	59.6	154	3.8	38	0.42	0.20	2.0
Cow pea	323	24.1	1.0	54.5	77	8.6	12	0.51	0.20	1.3
Field bean, dry	347	24.9	0.8	60.1	60	2.7	0	0.52	0.16	1.8
Green gram Whole	334	24	1.3	56.7	124	4.4	94	0.47	0.27	2.1
Green gram dhal	348	24.5	1.2	59.9	75	3.9	49	0.47	0.21	2.4
Peas dry	315	19.7	1.1	56.5	75	7.05	39	0.47	0.19	3.4
Peas roasted	340	22.9	1.4	58.8	81	6.4	18	0.47	0.21	3.5
Rajmah	346	22.9	1.3	60.6	260	5.1	–	–	–	–
Red gram dhal	335	22.3	1.7	57.6	73	2.7	132	0.45	0.19	2.9

Source: Gopalan C., B.V. Rama Sastri and S.C.Balasubramanian, 1991, Nutritive value of Indian foods, National Institute of Nutrition, ICMR, Hyderabad.

dioxide, hydrogen and small amount of methane. Fermentation, germination, cooking, soaking and autoclaving reduce considerable amount of oligosaccharides.

Lipids

Pulses contain 1.5% lipids on moisture free basis. They contain high amounts of polyunsaturated fatty acids. Along with cereals they meet the requirements of essential fatty acids for an adult. Apart from linoleic acid most legume seed oils contain high proportion of linolenic acid. They undergo oxidative rancidity during storage resulting in loss of protein solubility, off flavour development and loss of nutritive quality. Oleic, stearic and palmitic acids are also present.

Minerals

They contain calcium, magnesium, zinc, iron, potassium and phosphorus; 80% of phosphorus is present as phytate phosphorus. Phytin complexes with proteins and minerals and renders them biologically unavailable to human beings and animals. Processing such as cooking, soaking, germination and fermentation can reduce or eliminate appreciable amounts of phytin. In amounts used, pulses do not contribute much to the total mineral intake.

Vitamins

Legume seeds are excellent source of B complex vitamins particularly thiamin, folic acid and pantothenic acid. Like cereals they do not contain any vitamin A or C but germinated legumes contain some vitamin C.

PFA standards for pulses is given in Table 3.4.

Digestibility of pulses

Among legumes, chick pea protein has high digestibility. Other legumes including lentils and phaseolus varieties have low digestibility.

Table 3.4: PFA standards for pulses

Test	*Red gram dhal*	*Green gram dhal*	*Black gram dhal*	*Bengal gram dhal*
Moisture Max %	14	14	14	16
Foreign matter Max %	2	2	2	2
Other edible grains Max %	0.5	4	4	2
Damaged grains Max %	5	5	5	5
Weevilled grains Max %	3	3	3	3
Uric acid mg Maximum per kg.	100	100	100	100

Polyphenolic compounds in human studies have been found to account

products. Bengal gram is tied in a moist cloth and kept overnight before it is parched. Peas are soaked in water for 5 minutes, dried partially in the sun for 15 minutes and then parched. Salt and turmeric powder are sometimes added to the steeping water or the grains smeared with the paste of the same before they are parched. Parching is done in a hot iron vessel containing sand at 190-200°C for 60-80 seconds. Parched bengal gram has been used successfully in the treatment of protein calorie malnutrition in children.

Extrusion

Blends of cereal and legume flours are extruded at high temperature (140-200°C) high pressure and a moisture content < 20 per cent. The product is cooked for a short time (30-60 sec) and the product is forced out of the extruder through a variety of *dies* and dried on conveyor belts.

STORAGE AND INFESTATION

Important problems in industrial or home processing of food legumes are to be found not only in their physical inherited characteristics but also in those that often develop during storage and handling after harvest. If storage conditions are not adequate the problems that may arise are

- insect and mould infestation.
- losses during milling or home preparation and
- increased cooking time.

All these may cause high physical losses as well as reduction in nutritive value.

Storage also decreases protein quality through heat damage resulting in a lower available lysine. Figure 3-c shows that beans become harder with increased storage period, require more time to cook due to decrease in phytic acid and increase in PCMP number during storage.

TOXIC CONSTITUENTS

Some pulses used in food contain chemical constituents having toxic properties.

Trypsin inhibitors

Trypsin inhibitors are proteins that inhibit the activity of trypsin in the gut and interfere with digestibility of dietary proteins and reduce their utilisation. Pancreas enlargement and growth retardation occur in animals that consume diet containing trypsin inhibitors. The release of essential amino acids, particularly, methionine is hampered by the presence of inhibitors. They are generally heat labile. Autoclaving at 120°C for 15-30 minutes inactivates almost all trypsin inhibitors. Trypsin inhibitors are easily inactivated from dhals but more drastic heat treatment is necessary to inactivate trypsin inhibitors of soyabean and kidney bean. These inhibitors prevent degradation of storage proteins during seed maturation.

Goitrogens

These substances interfere with iodine uptake by thyroid gland. Thiocyanate, isothiocyanates and their derivatives are present in soyabean, groundnuts and lentils. Excessive intake of these foods in the face of marginal intake of iodine from foods and water may lead to precipitation of goitre.

Tannins

Tannins are condensed polyphenolic compounds. They are present in high amounts in seed coat of most legumes. Tannins bind with iron irreversibly and interfere with iron absorption. Tannins interfere with digestive action of trypsin and α-amylase rendering the dietary protein and carbohydrate indigestible. Tannins also bind proteins and reduce their availability.

Removal of seed coat of legumes reduces the tannin content. Removal of husk lowers tannin content and thus improve the appearance, texture, cooking quality, palatability, digestibility of the grain and bioavailability of nutrients. White coat beans have negligible quantity of tannins whereas black and red varieties have higher content of tannins. Red kidney bean, black gram and soyabean have higher amounts of polyphenolic compounds.

PULSE COOKERY

Mostly pulses are cooked and consumed and they take longer time to cook than cereals. The cooking process softens the hard seed by improving the plasticity of the cell wall, thus facilitating cell expansion and reduction of intercellular adhesion. Cell cementing material—pectin—is altered during cooking so that the cells of the beans separate with comparative ease.
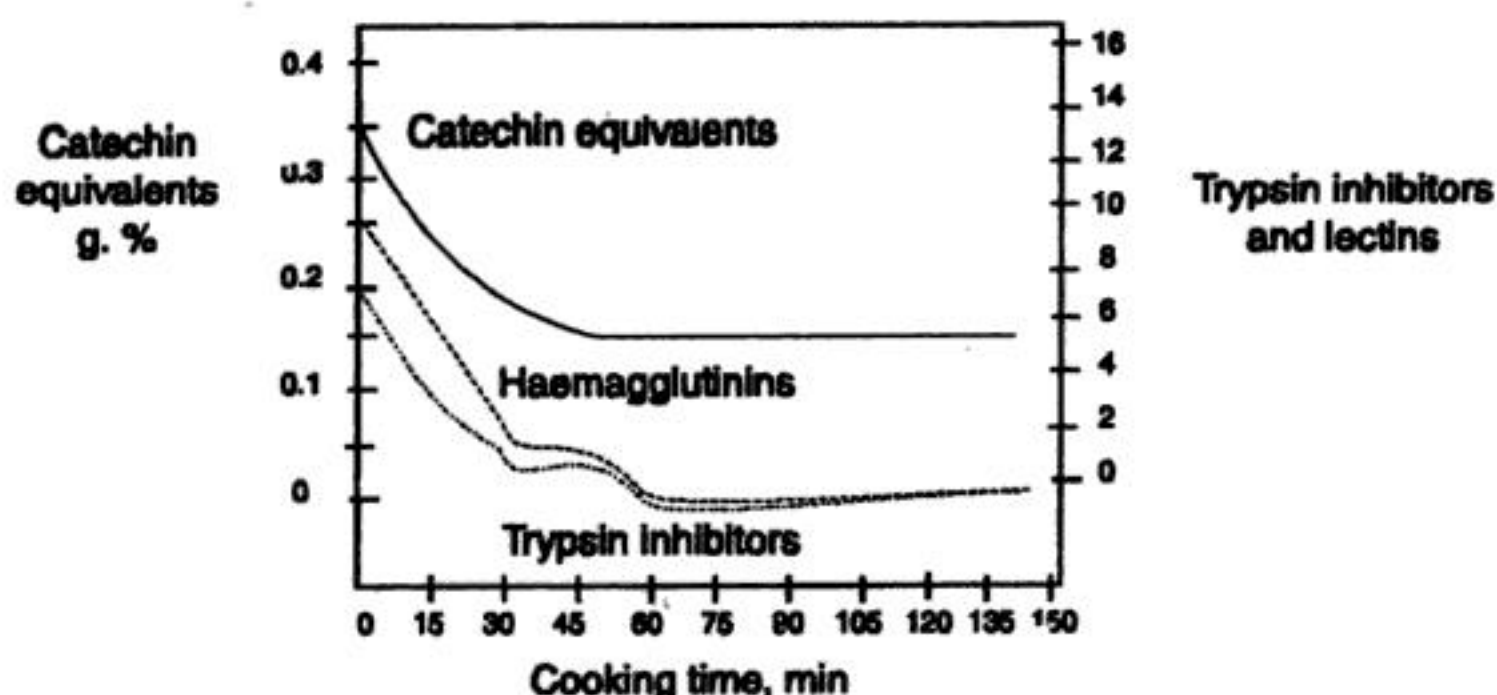
Figure 3-e: Effect of cooking on toxic factors of common bean.

Effect of cooking

Antinutritional factors: Uncooked legume seeds contain antinutritional factors that can be toxic if large amounts are consumed. Figure 3-e shows changes in trypsin inhibitors, haemagglutinins and polyphenolic compounds relative

MEDICINAL VALUES OF PULSES

Bengal gram consumed over a period of several weeks may reduce serum cholesterol levels by increasing faecal excretion of total bile acids.

Leguminous seeds and beans provide high fibre as well as antinutrients like phytates, tannins, saponins and enzyme inhibitors and their gradual absorption produces a lower rise of blood sugar than an equal amount of carbohydrate from other sources hence recommended to diabetics.

Guargum a gel forming galactomannan polysaccharide derived from the cluster bean has been shown to reduce plasma cholesterol in hyper cholesterolemic men. This is due to its ability to form a viscous gel in the small intestine which decreases cholesterol absorption and delivery of cholesterol to the liver by the chylomicron remnant, or its ability to bind bile acids which mobilise hepatic cholesterol pools due to an increased demand for bile acid synthesis.

Guargum also influences glucose tolerance. This may be due to viscosity, alteration in post-prandial responses to insulin and various gut hormones.

QUESTIONS

1. Discuss the nutritional contribution of pulses to the diet.
2. Explain the effect of germination on pulses.
3. Discuss the anti-nutritional factors of pulses.
4. Write a short note on lathyrism.
5. What is favism?
6. What are the factors affecting cooking of pulses?
7. Explain the different processings done on legumes.
8. What is parching of pulses? Give two recipes where parched pulses are used?
9. Describe the role of pulses in cookery.
10. What are the substances present in pulses which affect the digestibility? How can you overcome this?
11. What are tannins? Give their importance in pulses.

PRACTICALS

1. Demonstrate the factors affecting cooking quality of pulses.
2. Prepare recipes using whole gram, sprouted pulses, split dhals, parched pulses and pulse flours.
3. Prepare recipes using cereal and pulse combination.
4. Prepare recipes using fermented pulse products.
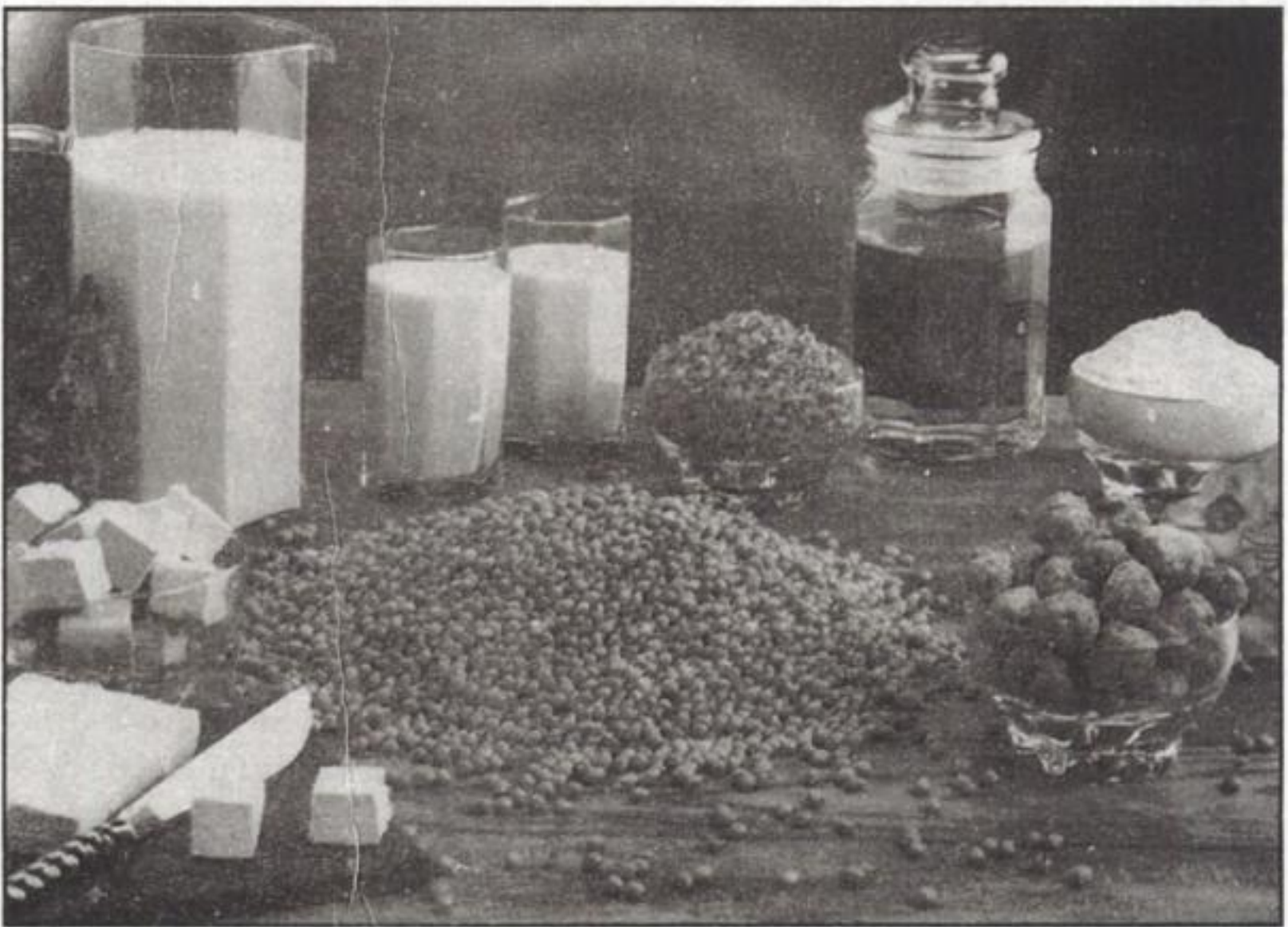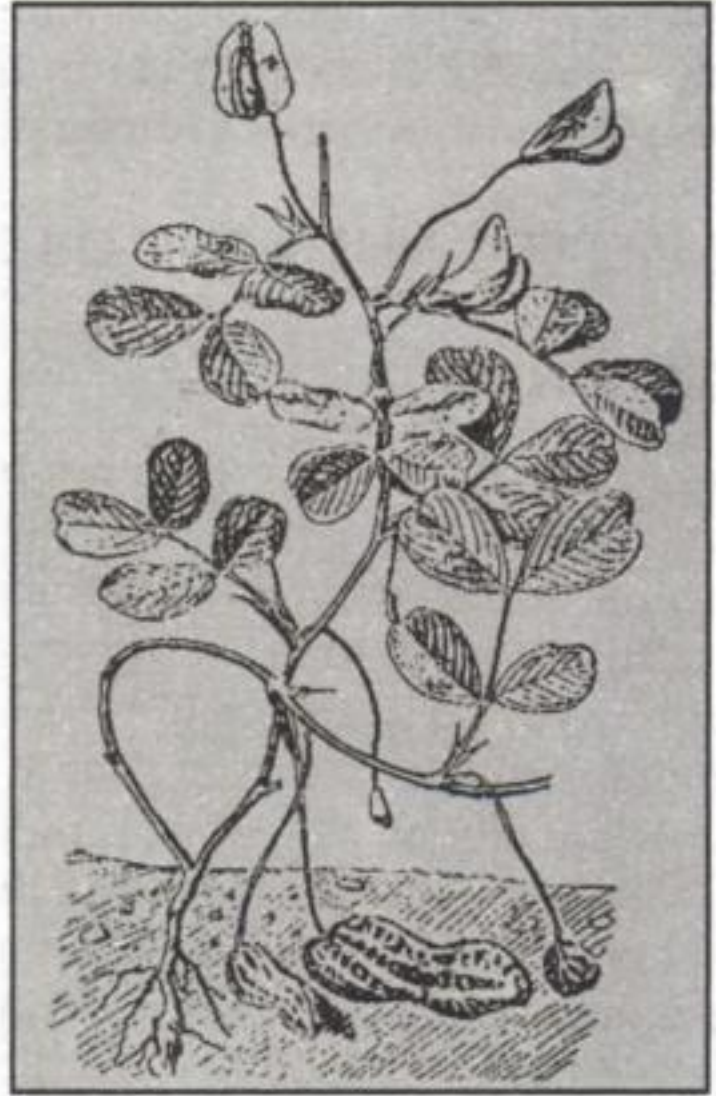
Figure 4-a: Hazel nuts, ground nut plant and soyabean and its products.

- Good quality peanut kernels are cleaned of impurities and roasted lightly and the red skin is removed.

dissolved in alkali and they form a sticky liquid and may be extracted through tiny holes and then recoagulated in an acid bath in the form of fibres. The fibres can be spun into ropes with texture of chicken or beef muscle tissue. The fabricated tissue then can be interlaced with fats, food flavourings and food colours. Products are almost indistinguishable from chicken meat, fish, hen or beef. This soyabean meat like products can be used by vegetarians and for patients with special dietary restrictions such as controlled levels of fat. TVP is cheaper than meat. Protein quality of TVP is lower than that of meat owing to the low methionine content of soyabean. The quality can be improved by using in combination with meat.

Tempeh

It is an Indonesian product. Tempeh is a white mould covered cake produced by fungal fermentation of dehulled, hydrated and partially cooked soyabean cotyledons. The fermenting agent is the fungus *Rhizopus oligoporous.* The fungus is added to cooked and mashed soyabean and is allowed to incubate for 24 hours. The fermented product contains 25 per cent original protein and the other half of the protein is broken down to amino acids. Tempeh is a dense, chewy textured soyafood with a nutty, slightly smoky taste like mushrooms. It is a good source of isoflavones, fibre, protein and due to fermentation even rich in vitamin B_{12}.

Natto

It is a Japanese product. The soyabeans are soaked in water cooked and inoculated with *Bacillus subtilis* or previously prepared Natto. They are then wrapped in barks of pines and are allowed to ferment under vacuum conditions at 40°C for 20 hours.

Soya sauce

Soyabeans are cooked for 4 to 6 hours and cooled. They are mixed with an equal quantity of roasted ground wheat and the mixture is seeded with *Aspergillus oryzae.* After the initial fermentation, salt is added and the product is matured for 6 months to 3 years. When ripening is complete, the product is strained. Soya sauce thus obtained contains 67 per cent moisture and 5 to 6 per cent protein. Salt tolerant homofermentative lactic acid *P. cerevisiae* or *L. delbruckii* and salt tolerant yeast *S. rouxii* are involved in maturation of the product.

Miso

It is another fermented soyabean paste widely used in Japan. It is made from whole soyabeans, salt, rice or barely and a fermented agent. Miso may be aged upto three years and has a very distinctive taste. As a condiment it is used to flavour soups and salad dressing sauces. It is rich in protein, isoflavones, antioxidants and sodium but low in fat.

Roasted soya nuts with many flavours and coatings are available. Edamame is prepared by cooking soyabean in their pods in boiling salted

endosperm. Glandless varieties of cotton seeds that are free of gossypol also have been developed by plant breeders.

Role of nuts and oilseeds in cookery

Nuts and oilseeds are used in cookery as whole, halved, flaked, nibbed, ground or desiccated.

a. Nuts are used in fresh, raw, roasted or boiled or salted forms and also fried forms.
b. Nuts are used as thickening agents. Coconut, poppy seeds and cashewnuts are used as thickening agents in the preparation of gravy.
c. Chutneys can be made and used from nuts, e.g. groundnut and coconut.
d. Sweets are made from nuts, e.g. chikki, burfi, kozhukattai, cashewnut cake.
e. Oil is used as cooking media for frying and seasoning. Oil is also used as preservative in pickles.
f. Powders made out of nuts like groundnut and coconut are used as chutneys and salad dressing.
g. Nuts are also used in ice-creams, cakes, pastries, payasams and chocolate.
h. Nuts are also used in beverages, e.g badam kheer.
i. Peanut butter is used as a topping on the bread or as a side dish along with chapatis.
j. Oilseed cakes are used as weaning food or as thickening agents in vegetables like capsicum.
k. Nuts are used as garnishing material—raw, roasted, salted or boiled forms.

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QUESTIONS

1. Explain the role of nuts and oilseeds in cookery.
2. What is aflatoxin? What are its harmful effects?
3. Give the nutritional value of groundnuts.

4. Give the stepwise procedure for preparing groundnut milk and soyabean milk.
5. Compare the nutritive value of groundnuts with cashewnuts.
6. What products can be prepared out of soyabean?

PRACTICALS

1. Prepare following recipes using nuts.
   a. Sweets
   b. Chutneys
   c. Salads
   d. Snacks.
2. Prepare recipes where nuts and oilseeds used as:
   a. Thickening agent.
   b. Garnishing agent.
   c. Major ingredients.

Chapter 5

MILK AND MILK PRODUCTS

Milk is one food for which there seems to be no adequate substitute. All mammals produce milk after the birth of the young ones and man uses milk of many animals as his food. The cow is the most important of all these animals as supplier of food. Buffalo and goat milk is also used.

COMPOSITION

Milk is a complex mixture of lipids, carbohydrates, proteins and many other organic compounds and inorganic salts dissolved or dispersed in water. The most variable component of milk is fat followed by protein.

The composition of milk varies with the species, breed, diet, lactational period and interval between milking. There is individual variation also.

Milk fat

Buffalo's milk contains 6.5% fat. Cow's milk contains 4.1% fat. Milk fat or butter fat is of great economical and nutritive value. The flavour of milk is due to milk fat. Milk is a true emulsion of oil-in-water. Fat globules are visible under a microscope. Each globule of fat is surrounded by a thin layer which is composed of a lipid-protein complex and a small amount of carbohydrate. The lipid portion includes both phospholipids and triglycerides.

Fat globules vary widely in size from 2-10 μm (micro metres) and in number 3×10^9 per ml. The larger fat granules come to the surface of milk more quickly due to low specific gravity and this can be observed in the transportation of milk.

The structure of fat globule is shown in Figure 5-a.

Milk fat is a mixture of several different glycerides. They contain about 64% fatty acids ranging from 4-26 carbon atoms. Milk contains considerable amount of short chain fatty acids which give the characteristic flavour and off flavour. Due to their low melting point –10 to 12°C, they give soft solid consistency to butter. Saturated fatty acids account for butyric and caproic acid 62% and unsaturated 37%. Of the unsaturated fatty acids 3.8% constitute polyunsaturated fatty acids. Other lipid materials present in milk are phospholipids, sterols, free fatty acids, carotenoids and fat soluble vitamins. Carotenes are responsible for the yellow colour of milk fat.

Milk fat absorbs volatile odour very readily. Milk, butter and cream should not be exposed to strong odours.

MILK PROTEINS

Casein

Casein constitutes 80% of the total nitrogen in milk. It is precipitated on the acidification of milk to pH 4.6 at 20°C. The remaining whey protein constitutes lactoglobulin and lactalbumin. Milk protein contains proteoses, peptones and milk enzymes.

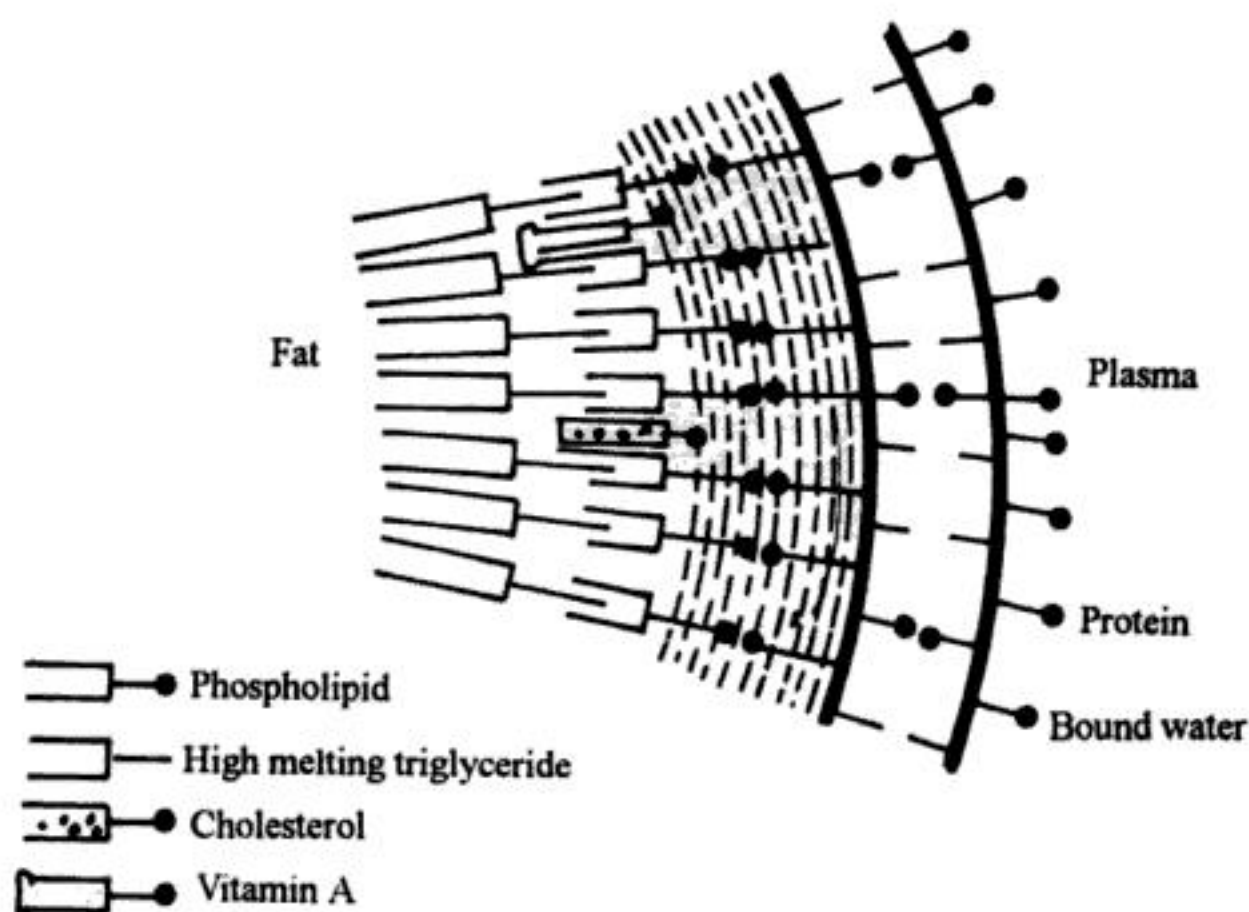



Figure 5-a: Structure of fat globule membrane in milk.

Source: Charley Helen, 1970, Food Science, John Wiley & Sons, Newyork.

Casein is classified as a phosphoprotein because of the phosphoric acid that is contained in its molecular structure. At the normal acidity of fresh milk (about pH 6.6) casein is largely combined through the phosphoric acid part of its structure with calcium caseinate. Hence casein occurs in milk as a colloidal protein calcium phosphate complex.

Casein is also a glycoprotein. Glutamic acid is the predominant one in casein. Proline, aspartic, leucine, lysine and valine are also present. Casein is a good source of essential amino acids. Casein contains 8.2% calcium and 5.7% carbohydrates.

Casein can also be separated from milk by the addition of rennin, an enzyme secreted by the young calves.

Whey proteins

Whey proteins are made up of α-lactabumin and β-lactoglobulin, serum albumin, the immuno globulins, enzymes and proteose—peptones. β-lactoglobulin accounts for about 50% of total whey proteins. These are not precipitated by acid or rennin, they can be coagulated by heat. Whey also contains small

amounts of lactoferrin and serum transferrin. By a process involving ultrafiltration, whey protein concentrate is produced. Whey protein isolates are also produced. It can be given in lactose intolerance.

Milk sugar

Milk contains 4-5% carbohydrate. The chief carbohydrate present in milk is lactose, a disaccharide, although trace amounts of glucose, galactose and other sugars are also present. Lactose gives on hydrolysis glucose and galactose. Lactose has only one sixth the sweetness of sucrose and one third-one fourth of its solubility in water. When milk is heated lactose reacts with protein and develops a brown colour. The development of brown colour is due to nonenzymatic browning. It is called Maillard reaction. The acid fermentation is used in making butter, cheese and curd.

Salts

Chlorides, phosphates, citrates, sulphates and bicarbonates of sodium, potassium, calcium and magnesium are present. These salts influence the condition and stability of the proteins, especially the casein fraction. Copper and iron are important in the development of off flavours in milk and milk products. In addition to this, milk contains trace elements like zinc, aluminium, molybdenum and iodine.

Enzymes

The enzymes found in milk can originate from the mammary glands or may be released by contaminating bacteria.

Alkaline phosphatase exists as lipoprotein and is distributed between the lipid and aqueous phases. This enzyme is inactivated by normal pasteurisation procedures and its activity is tested to determine the effectiveness of pasteurisation.

More than one type of lipase occurs in milk. Milk lipase is responsible for the development of rancid flavours in milk. Bacterial lipase is very resistant to heat and can cause serious quality defects. Lipases may be important in the development of desirable flavours in some cheeses.

Xanthin oxidase occurs in the fat globule membrane. It is a conjugated protein complexed with FAD, iron and molybdenum. The enzyme degradation of FAD gives FMN and riboflavin. The riboflavin content of milk may thus be due to xanthin oxidase. Xanthine oxidase can catalyse the oxidation of aldehydes which are some of the aroma constituents in fermented dairy products. The enzyme is not destroyed by pasteurisation.

Colour

White colour of milk is caused by the reflection of light by the colloidally dispersed casein, calcium and phosphorus. Yellowish colour of milk is due to the presence of carotene and riboflavin. Fat soluble carotenes are found in milk fat; riboflavin is water soluble which can be visible clearly in whey water.

Flavour and Aroma

Milk is slightly sweet because of its lactose content. Flavour sensation in mouth is due to fat protein and some of the salts such as calcium phosphate. The slight aroma of fresh milk is produced by a number of low molecular weight compounds such as acetone, acetaldehyde, dimethyl sulphide and short chain fatty acids. Some of the volatile compounds to the flavour of milk are unique to the fat portion of milk. Boiling changes the flavour of fresh milk more than pasteurisation.

Oxidised flavour can result from the oxidation of phospholipids in the milk. Since traces of copper accelerate the development of oxidised flavour, copper containing equipment is not used in dairies. Some of the poly-unsaturated fatty acids are particularly susceptible to auto oxidation in the presence of oxygen and unpleasant flavour substances are produced.

Off flavour in milk may be influenced by the health of the cow or the feeds that are consumed by the cow, action of bacteria, chemical changes in milk, or the absorption of foreign flavours after the milk is drawn.

Off flavours are also produced when milk is exposed to light. In this reaction tryptophan and riboflavin may be involved and their content decreases when the off-flavour develops.

Anything that alters the membrane and permits contact of the lipases with the fat will promote rancidity and off flavour.

PHYSICAL PROPERTIES

Physically, milk is a dilute emulsion, colloidal dispersion and true solution.

Acidity

Fresh milk has a pH of about 6.5-6.7 at 25°C. As milk stands exposed to air, its acidity decreases slightly because of the loss of carbon dioxide. Raw milk, which normally contains some lactic acid producing bacteria gradually increase in acidity on storage. Pasteurisation destroys lactic acid bacteria.

Viscosity

Factors affecting viscosity of milk are state and concentration of the protein and fat, temperature of milk, age of milk. Conditions and treatments that affect the stability of casein are important in the viscosity of milk such as acidity, salt balance, heat treatment and the action of various enzymes and bacteria. Viscosity depends on the amount of fat, size of the fat globules and the extent of clustering of the globules. Homogenisation and ageing increase the viscosity.

Freezing point

The freezing point of milk is –0.55°C. The freezing point is affected by the soluble constituents, lactose and ash which are constant. This fact makes it possible to determine whether or not milk is diluted. Addition of 1% of water to milk decreases freezing point by –0.0055°C.

Boiling point

Milk boils at 100.2°C at which temperature all organisms are destroyed. The loss of nutritive value of boiled milk is more than compensated by the avoidance of milkborne diseases.

NUTRITIVE VALUE

Table 5.1 gives the nutritive values of milk and milk products.

Milk has good quality protein and the biological value is over 90. Though milk contains only 3-4% protein, due to the quality of protein and the amount that can be ingested and the presence of other nutrients makes it indispensable. Lysine is one of the essential amino acids which is abundant in milk proteins. Cheese, khoa and dehydrated milk powders are concentrated forms hence contain high amount of nutrients per unit.

Milk is the only substance that contains lactose, which has galactose which is essential for the synthesis of myelin sheath. Lactose, not being easily soluble favours the growth of lactic acid bacilli in the intestine, which decreases the pH. This drop in pH favour calcium absorption. Lactose also increases the permeability of the small intestine for calcium ions. Milk sugar due to its controlled glycaemic effect, is preferred as a source of carbohydrate.

The fat of milk is easily digestible. It contains linoleic acid (2.1%) linolenic acid (0.5%) and arachidonic acid (0.14%). Skimmed milk does not contain any fat. Buffalo milk contains high amount of fat.

Dairy foods are a major source of calcium because of the significant amount of the minerals present. The calcium-phosphorus ratio (1.2:1) in milk is regarded as most favourable for bone development. In addition, dairy products contain other nutrients such as vitamin D and lactose which favour calcium absorption. The calcium requirement cannot be met easily without taking milk.

Mineral content of Aavin milk (100 ml)

Calcium mg	- 125
Sodium mg	- 50
Magnesium mg	- 10
Potassium mg	- 150
Phosphates mg	- 210
Citrate mg	- 200
Chloride mg	- 100
Bicarbonate mg	- 20
Sulphate mg	- 10

Source: The Tamilnadu Cooperative milk producers' federation Ltd.

Milk is a poor source of iron. But whatever little iron is present, it is utilised in the body. Khoa contains more amount of iron because during the process it gets from the containers.

Thiamine occurs in only fair concentration in milk, but is relatively constant in amount. Riboflavin is present in a higher concentration in milk than the other B-vitamins and its stability to heat makes milk a dependable source of this vitamin. In cheese making, riboflavin is present in whey water. Since it is sensitive to light, when milk is exposed to sunlight 50% of riboflavin is lost.

Milk is not a good source of niacin but it is an excellent source of tryptophan.

Milk is a very poor source of vitamin C. The amount of vitamin A and D depend on the feed of the animal.

EFFECTS OF HEAT

Protein

On heating, lactalbumin and lactoglobulin become insoluble or precipitate. Lactalbumin begins to coagulate at a temperature of 66°C. The amount of coagulum increases with increasing temperature and time of heating. The coagulum that forms appear as small particles rather than a firm mass and collects on the bottom of the pan in which the milk is heated.

The protein found in largest amount in milk, casein, does not coagulate at the usual temperatures and times used in food preparation. Casein coagulates at 100°C heated at 12 hours or at 135°C to one hour or at 155°C to 3 minutes. The resistance of casein to heat is because it is in combination with a definite amounts of calcium, magnesium, phosphorus and citrate in milk.

Heating periods that produce casein coagulation are shorter when the concentration of casein is increased above the regular fluid milk. For example in the sterilisation of canned evaporated milk, it is necessary to take certain measures to prevent coagulation of the casein. One such measure is to prewarm the milk prior to its sterilisation. When milk is heated the albumin forms a flocculant precipitate that settles on the sides of the container.

The coagulation of milk proteins by heat is accelerated by an increase in acidity. It is also influenced by the kind and concentration of salts present. The reaction of salts and tannins on coagulation of casein is enhanced by heat.

Fat

The layer of fat that may form on milk that has been boiled results from the breaking of the films of proteins that surround the fat globules in the unheated milk. The breaking of films of emulsifying agents permits the coalescence of fat globules.

Sugar-protein mixtures

Nonenzymatic browning of Maillard type occurs in evaporated milk. Maillard (1912) was the first to describe the development of brown colour in mixtures containing amino acids and reducing sugars. The maximum effect is with lysine, followed by tryptophan and arginine. Glucose reacts more strongly with lysine than lactose or fructose, while lactose reacts most readily with tryptophan.

The steps involved in the Maillard reaction between reducing sugars and amino acids or proteins are as follows:

(a) Condensation of the aldehyde or ketone group with the amino group.
(b) Rearrangement of condensation products.
(c) Dehydration of the rearranged products.
(d) Further degradation and
(e) Polymerisation to brown pigments.

Sucrose does not react by itself as it has no reacting group but the hydrolytic products of sucrose, glucose and fructose react with amino acids. If proline is involved in the reaction the product may become bitter.

The rate of browning increases rapidly with a rise in temperature. The colour development increases with increasing pH above 6.8 for glucose—α-amino acid solutions and above pH 6.0 with glucose—ω-amino acids. The involved amino acids are no longer biologically available.

The reaction rate being decreased at low or very high water levels although the dry materials will react. The optimal moisture levels for the reaction range from 10-15 per cent in a dehydrated product. The reaction is catalysed by the presence of metals such as iron and copper and by phosphate ions.

Concentrated milk products such as evaporated milk and sweetened condensed milk contain substantial amounts of both protein and the sugar lactose and develop some brown colour on heating. This reaction may also occur in dried milk stored for long periods.

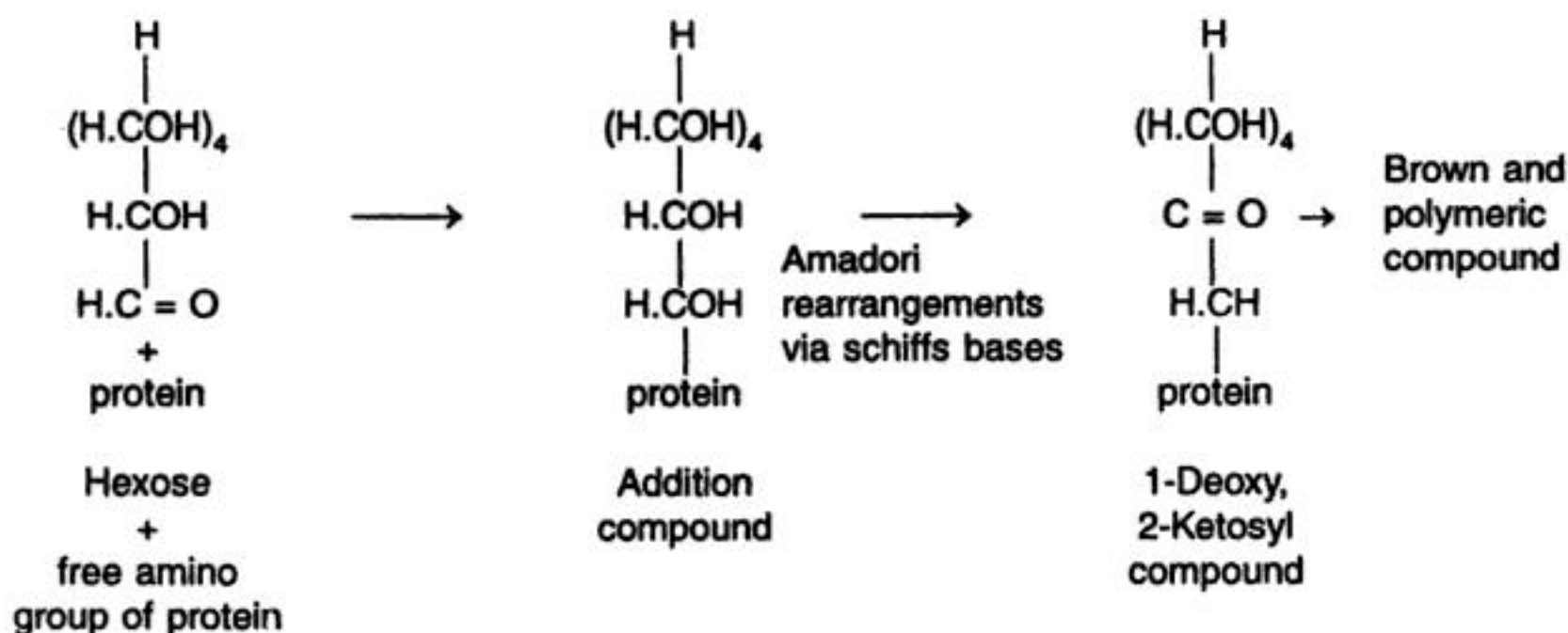



Figure 5-b: Simplified outline of the Maillard reaction.

Source: Passmore R., M.A. Eastwood, 1987, Davidson and Passmore Human Nutrition and Dietetics, English Language Book Society/ Churchill Livingstone.

Acid

When milk is heated its acidity decreases at first owing to the release of dissolved carbon dioxide and then increases because hydrogen ions are liberated when calcium and phosphate forms insoluble compounds. A balance between these opposing factors prevents large changes of pH during heating.

Minerals

Iodine is a volatile substance and when heated tends to be lost from milk. The dispersion of calcium phosphate in milk is decreased by heating and part of it is precipitated. Some of it collects on the bottom of the pan with coagulum of albumin and some is probably entangled in the scum on the top surface of the milk.

Colour, flavour and digestibility

Neither the flavour nor the general appearance of milk is appreciably changed by pasteurisation. Cooked flavour of boiled milk is due to loss of dissolved gases like carbon dioxide and oxygen and the changes that occur in protein. Digestibility may be slightly improved. Heated milk tends to form smaller and more tender curds in the stomach compared to raw milk.

Microorganisms

Destruction of microorganisms take place at higher temperature.

Scum formation

Scum is formed when milk is heated in an uncovered pan on the surface due to drying out. The scum gets toughened as the temperature is increased. The insoluble scum can be removed from the surface but another one forms. It contains a small amount of coagulated protein, minerals and fat globules. A tenacious layer of fat that forms on the milk when heated is due to the breaking of the film of the protein that surrounds the fat globules in unheated milk resulting in coalescence of fat globules. Scum formation can be prevented by heating or stirring the milk while heating it. Use of a milk boiler helps to prevent it. It can be prevented by covering the pan or by diluting the milk.

Scum formation during the heating of milk is the principle reason for its behaviour of boiling over. A certain amount of pressure develops under the scum which later forces this scum upwards and the milk flows over the sides of the pan.

Scorching of milk

Scorching is due in part to the film of coagulated albumin and other whey proteins that collect on the bottom and sides of the pan. Nonenzymatic browning may be responsible for the brown colour of scorched milk. Heating milk over hot water like milk cooker can prevent this. Stirring to some extent can also prevent this. Homogenised milk coagulates more readily than non-homogenised milk. This is due to increased amount of protein on the surface of the uniform fat globules and due to the variations in the temperatures and pressures used for homogenisation.

EFFECTS OF ACID

At pH 6.6, casein is present largely as calcium caseinate. When the acidity of milk is increased either by the addition of acid or by natural souring, the acid

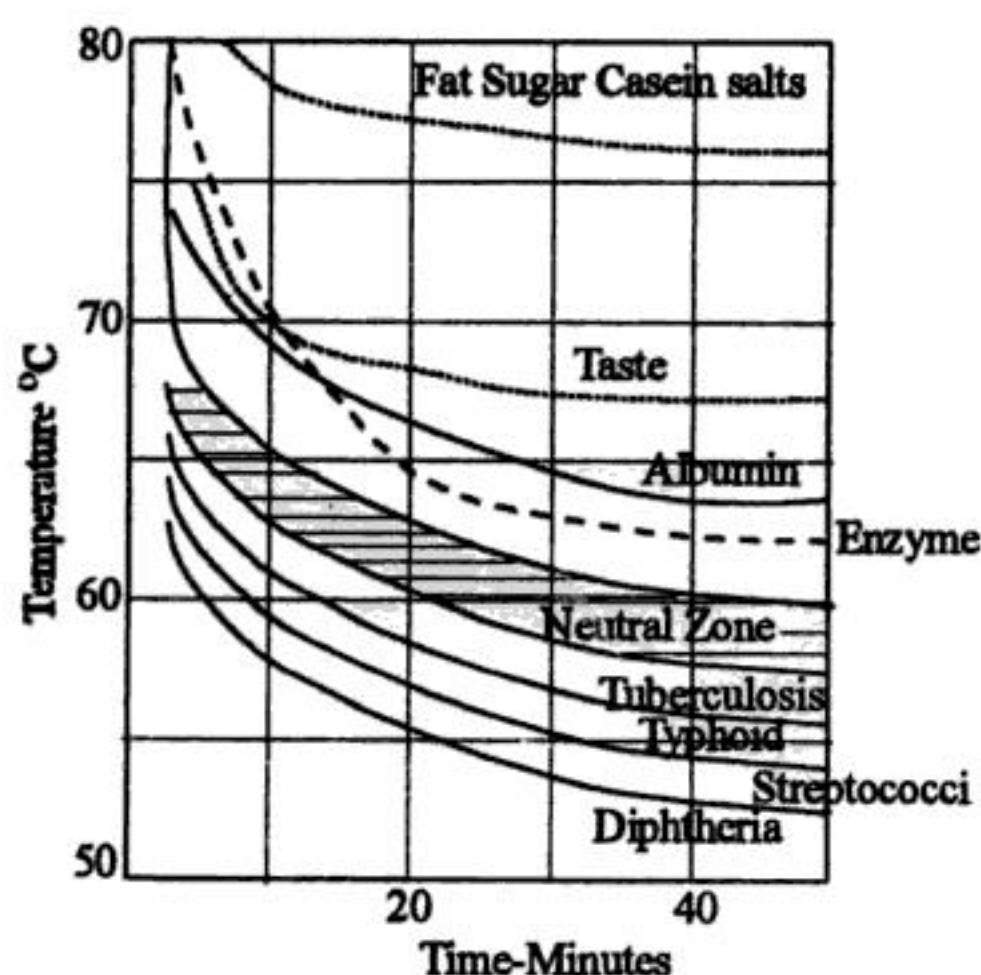



Figure 5-c: Effect of heat on milk.

Source: Hall and Trout, 1968, Milk pasteurisation, AVI Publication Company.

removes calcium and phosphate from calcium caseinate changing it into casein. Casein coagulates when the pH has been reduced to about 5.2 and is least soluble at its iso-electric point pH 4.6. When the pH reaches about 4.6, the colloidally dispersed casein particles become unstable. They adhere together and form a coagulm or curd. This probably occurs because the usual negative charge on the casein particles, which causes them to repel each other and remain apart, is neutralised by acidic hydrogen ion.

The precipitated casein can be rendered soluble by additional acid or alkali either of which shifts the pH away from the iso-electric point. Bacterial action in milk can also lower the pH of the milk and precipitate casein as curd. In making curd and cheese this reaction is desirable. Cream of tomato soup is a product in which the prevention of casein coagulation or curdling is needed. Fruit milk shakes may also curdle and this can be prevented by lowering the temperature of the ingredients, e.g., mango milk shake. Higher temperature hastens the action of acid coagulation.

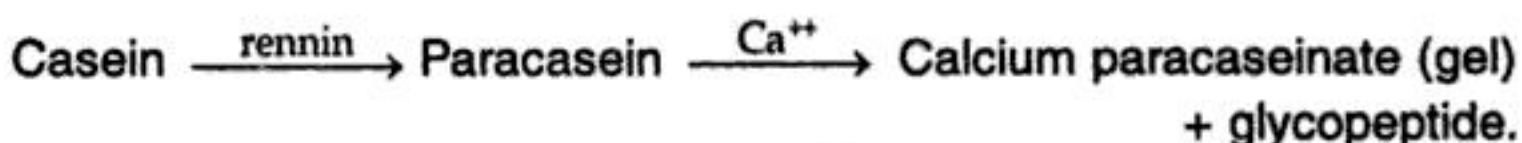
EFFECTS OF ENZYMES

Rennin (Chymosin)

Rennin, an enzyme secreted by the young calves, brings about the coagulation of milk. The coagulation is due to the change in the physico-chemical status of casein, as a result of the cleavage of a particular peptide bond (between phenylalanine and methoionine) in the K-casein fraction. This results in the release of a peptide. The remaining protein is no longer soluble and it cannot act as a stabilising agent for micellar proteins. Hence, an insoluble casein gel is

formed. Next rennin acts as a general proteolytic enzyme on all the protein components.

When casein is precipitated by the action of rennet, the calcium is not released to the whey but remains attached to the casein. Therefore, cheese made with rennet is a much better source of calcium than cheese made by acid precipitation alone. Cottage cheese is often made by acid precipitation.

$$\text{Casein} \xrightarrow{\text{rennin}} \text{Paracasein} \xrightarrow{Ca^{++}} \text{Calcium paracaseinate (gel)} + \text{glycopeptide.}$$

Factors affecting rennin coagulation

- *Temperature:* The optimum temperature is 40-42°C. Low temperature retards the reaction and produces a more tender coagulum. Higher temperature within the range of activity tends to toughen the coagulum. No action occurs below 10°C or above 65°C.
- *Heating milk before enzyme action:* Heating milk to temperature over 65°C prior to the addition of rennin retard or may entirely prevent the formation of firm clot. By heating, the casein is made more resistant to coagulation by rennin. Pasteurisation temperatures do not affect the action of rennin.
- *pH of the milk:* Rennin acts best in a faintly acid medium at 5.8 pH but milk that is acidic enough to curdle is not coagulated by rennin. Rennin action does not occur in an alkaline medium.
- *Concentration of constituents:* Diluting milk, dilutes the casein and calcium. Rennin reacts with diluted milk to form less firm clots and the reaction is noticeably retarded. An excess of sugar may tend to prevent the formation of clot by rennin.
- *Salts:* Monovalent ions reduce clotting tendencies and divalent and trivalent cations hasten coagulation.
- *Agitation:* The clot formed by rennin is easily broken by stirring and cause sineresis or separation of the watery portion of the milk.

Fruit enzymes

Bromelin, a proteolytic enzyme, from pineapple digests proteins hence changes the gelation to compounds that do not form a gel. The enzyme bromelin clots the milk and digests the clot. All fruits contain some organic acids but not always in sufficient concentration to cause the curdling of milk. Destroying of the enzymes before combining the fruit with milk prevents curdling caused by the enzyme action, by blanching or by using canned fruits.

EFFECT OF PHENOLIC COMPOUNDS (TANNINS) AND SALTS

Fruits and vegetables contain tannins chiefly in green stages. Curdling of milk may occur if tannin containing foods such as potatoes are cooked in the milk. Tannins are also present in brown sugar and cocoa products.

Seeds and stems may contain significant amount of phenolic substances. Among vegetables, the roots, pods, some seeds and woody stems are likely to contain more phenolic compounds than other parts of the plant, although distribution is general throughout the plant.

Salts present in milk or food or addition of sodium chloride can curdle the milk.

MICROORGANISMS

Milk is an excellent medium for the growth of microorganisms. The odour of milk is due to the activity of the micro organisms. Milk can be contaminated from the udders to the vessels. Good hygeinic conditions are to be used at all levels of milk handling to keep the bacterial count level low.

Freshly drawn milk is cooled immediately to 4°C to arrest micorbial growth or heated to boiling to destroy them. If raw milk is placed at room temperature a number of fermentative changes take place. Curdling may occur due to lactic acid produced by bacteria. Some bacteria produce in addition to acid some gaseous products while others bring about proteolysis of casein resulting in off flavour and unpleasant odour. There are also bacteria which bring about ropiness in milk.

When acid is increased in milk, moulds and yeasts present in milk flourish. They utilise the acid and bring about chemical changes producing an alkaline condition. Tuberculosis, typhoid fever, sore throat, gastroenteritis and diphtheria organisms may be present in contaminated milk.

Some micro-organisms bring about desirable changes by forming volatile acid like acetic acids and control the flavour and aroma. These are used in making butter, curds and other fermented products.

PROCESSING

It helps to produce milk that has initial low bacterial count, good flavour and satisfactory keeping qualities. There are three operations of milk processing and they are clarification, pasteurisation and homogenisation.

Clarification

Milk is passed through a centrifugal clarifier. The speed is adjusted in such a way that cream is not separated but dirt, filth and cells from the udder and some bacteria are removed. The clarified milk is ready for pasteurisation.

Pasteurisation

Pasteurisation derives its name from the French scientist Louis Pasteur who, found that heating of certain liquids to a high temperature improved their keeping quality. In general terms, it is the heating of milk to a temperature which destroys organisms responsible for tuberculosis and fever and nearly all the other microorganisms present in that product without seriously affecting the composition or properties of the product. Pasteurisation should be followed by immediate cooling of the product to the temperature sufficiently low to check the growth of microorganisms which are resistant to the temperature

used. At present, pasteurisation is considered as an essential feature in the manufacture of butter, ice-cream and also in cheese industries. Pasteurisation also inactivates some of the natural enzymes like lipase.

Three general methods are in use nowadays.

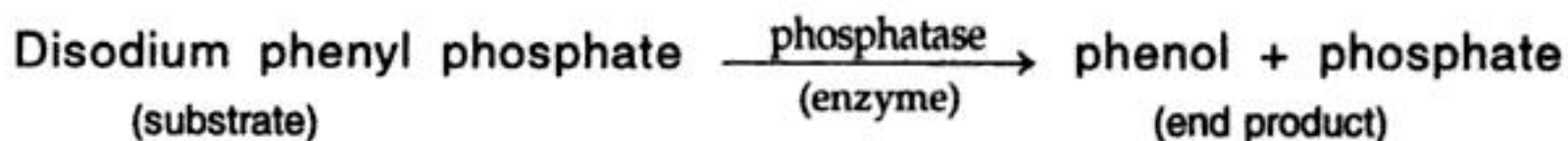
Holding or Batch System: The holding system consists in bringing the milk or cream to a temperature usually 65°C and holding at that point for at least 30 minutes followed by rapid cooling. A higher temperature is sometimes used in which case the time of holding may be shortened. For example, holding at 68.3°C for 20 minutes. Careful control of both temperature and time of heating is important.

High Temperature Short Time Method (HTST) or the Continuous System: The machines used are so constructed as to make possible a continuous operation and for this reason the system is called as "continuous flow or flash pasteuriser." The system depends upon the raising of the temperature of the milk to at least 72°C for 15 seconds as it passes through the machine. This is followed by quick cooling. This method does not impart cooked flavour and cream line is not affected.

Ultra High Temperature System: This UHTS system results in a complete pasteurisation of milk. In this system milk is held for 3 seconds at 93.4°C or for one second at 149.5°C. This system is also used extensively for the treatment of milk or cream in dairy industries. This product has a longer shelf life than milk pasteurised by other methods. After pasteurisation, the milk is cooled rapidly to 7°C or lower.

Role of Phosphatase in Pasteurisation

Raw milk contains alkaline phosphatase. This enzyme serves as a built-in indicator by which the adequacy of pasteurisation may be gauged. This enzyme has heat destruction characteristic that closely approximates the time, temperature, exposures of proper pasteurisation. Therefore if alkaline phos-phatase activity beyond a certain level is found in pasteurised milk it is evidence of inadequate processing. This enzyme has the ability to liberate phenol from phenol phosphoric acid compound. The liberated phenol gives a deep blue colour with certain organic compounds. If the milk is incubated it does not give blue colour with the indicator it means the pasteurisation is complete.

$$\underset{\text{(substrate)}}{\text{Disodium phenyl phosphate}} \xrightarrow[\text{(enzyme)}]{\text{phosphatase}} \underset{\text{(end product)}}{\text{phenol + phosphate}}$$

So sensitive is this test that it gives positive in the presence of 0.1% raw milk added or if the pasteurisation temperature is less by 1 degree F.

Effect of Pasteurisation

Nutritive value: Due to pasteurisation there is no important change in nutritive value, except for the slight decrease in the heat labile vitamins like thiamine and ascorbic acid. Whey proteins are denatured only slightly and minerals are not appreciably precipitated. Pasteurised milk produces finer curd when milk is digested.

Flavour: Pasteurisation does not produce objectionable cooked flavour. The flavouring compounds present in milk are in no way destroyed by pasteurisation.

Microorganisms: Pasteurised products are not sterile. They contain vegetative organisms and spores still capable of growth. Pathogens like *mycobacterium tuberculosis, salmonella typhi, corynebacterium diphtheria* and *brucella* are destroyed but non-pathogens remain in the milk even after the pasteurisation is complete. Approximately 99% of bacteria, yeast and moulds are destroyed by pasteurisation. The milk does not contain heat resistance moulds and yeast.

Enzymes: Apart from phosphatase, lipase also gets inactivated which would have affected adversely the quality.

Schematic diagram 5-d shows the steps involved in pasteurising milk at Madhavarm Milk Dairy, Chennai.

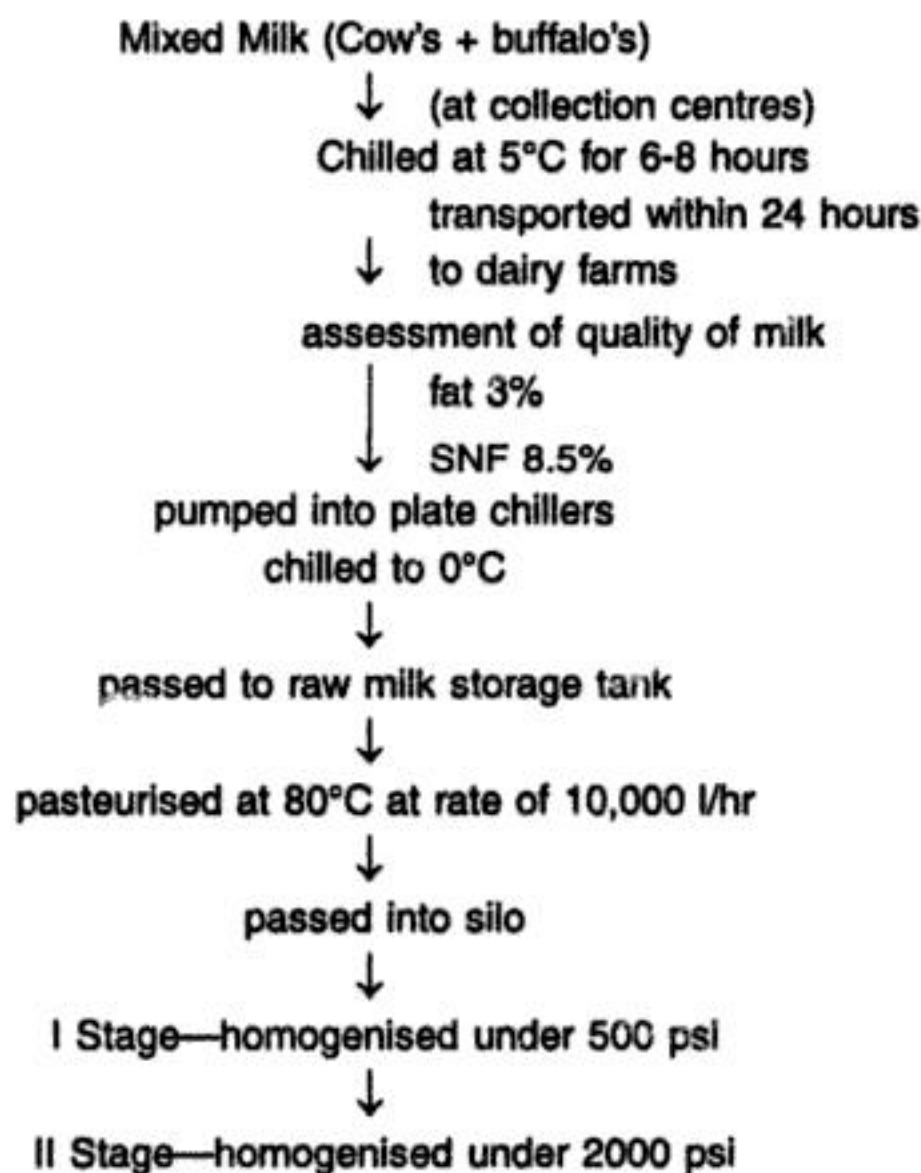



Figure 5-d: Processing of milk at Madhavaram Milk Dairy, Chennai.

After pasteurisation, tests for temperature, fat, specific gravity, solids-non-fat, acidity and bacterial analysis are conducted.

Pasteurised milk can be stored for a week or more in good condition. At room temperature it may be spoilt in a day.

Homogenisation

The process of making a stable emulsion of milk fat and milk serum by mechanical treatment and rendering the mixture homogeneous is homogenisation. This is achieved by passing warm milk or cream through a small aperture under high pressure and velocity. Milk and cream have fat globules that

vary from 0.1-20 µm in diameter. The fat globules have a tendency to gather into clumps and rise due to their lower density than skimmed milk. Homogenised milk fat globules size is 2 µm. The decrease in the size of the fat globules increases their number and surface area. A film of adsorbed protein or lipoprotein immediately surrounds each of the new globules, acting as an emulsifier and prevents them from reuniting. The newly formed fat droplets are no longer coated with the original membrane material. This brings about the stabilisation of milk emulsion and thus prevents the rising of the cream.

Homogenised milk has a creamier structure, bland flavour and whiter appearance. It has a greater whitening powder when added to coffee and tea. A soft curd is formed when coagulated and is easily digested. In the manufacture of evaporated milk (condensed milk) and ice-cream homogenisation reduces the change of separation of fat resulting in a smoother texture of the finished product. Homogenisation accelerates the action of lipase and rancidity of fat takes place. Homogenisation is done before pasteurisation.

Freezing

When milk or cream is frozen at a relatively slow rate, the film of protein that acts as an emulsifying agent around the fat globules is weakened and ruptured. As a result, the fat globules tend to coalesce. The dispersion of protein and calcium phosphate is also disturbed by freezing. Both constituents tend to settle out on thawing and standing, thus reducing the whiteness of milk.

MILK PRODUCTS

Milk is not only used as such but many products, nonfermented and fermented are used in cookery.

NONFERMENTED PRODUCTS

Whey protein concentrate

The milk is first coagulated by application of either rennet or acid. Whey is passed through the membranes called ultrafiltration technology to concentrate protein to various levels between 20-80%. Bioactive components found in whey are retained and concentrated, e.g. cysteine stimulates glutathione system which is a powerful antioxidant. The biological value and protein efficiency ratio is high.

Whey protein concentrate can be used in cookery and the role in food preparations is given in Table 5.2.

Skim Milk

Fat content is reduced to 0.5-2% by centrifugation. By removing fat from the milk not only taste or flavour is reduced but fat soluble vitamins like vitamin A and D are reduced. Usually this milk is fortified with vitamins A and D. Condensed skim milk finds extensive use in the baking industry and manufacture of confectionery. Skim milk is used for low calorie diets and for children who need high protein.

Evaporated milk

This is the milk from which about 50-60% of the water has been evaporated. Raw milk is clarified and concentrated in a vacuum pan at a temperature of 74-77°C. It is fortified with vitamin D, homogenised, sterilised in cans at a temperature of 118°C for 15 minutes and cooled. This heat treatment gives evaporated milk a light brown colour owing to sugar protein interaction and its characteristic flavour. As per PFA rules, the condensed milk should contain 26 per cent milk solids of which 8 per cent is fat.

Table 5.2: The role of whey protein concentrate in food preparations

Functional Property	*Mode of action*	*Food system*
Whipping/Foaming	Forms stable film	Eggless cakes, desserts, whipped toppings
Emulsification	Formation and stabilisation of fat emulsion	Vegetarian sausages, salad dressings, coffee whiteners, soups, cakes, infant food formulas, biscuits.
Gelation	Protein matrix formation and setting	Meats, baked goods, cheeses
Viscosity	Thickening, water binding	Soups, gravies, salad dressings
Water binding	Hydrogen bonding of water; entrapment of water	Meats, sausages, cakes, breads
Solubility	Protein solubility	Beverages
Browning	Undergoes Maillard Reaction	Breads biscuits, confectionery, sauces
Flavour/Aroma	Lactose reacts with milk proteins	Baked goods, biscuits, confectionery, sauces, soups, dairy products

Sweetened condensed milk

Sweetened condensed milk unlike evaporated milk is not sterile. Multiplication of microorganisms in the product is prevented by the preservation action of sugar. The product is made from pasteurised milk that is concentrated and sweetened with sucrose. Sugar concentration is 65%. This milk cannot be substitute for the ordinary fresh milk for children. As per PFA rules the milk solids should be about 31 per cent of which 9 per cent is fat.

Dry milk

Dry milk can be made with whole milk or skimmed milk. Milk powder can be dehydrated to about 97% by spray drying and vacuum drying. Good shelf life without refrigeration of dry milk makes it a valuable milk product. Milk powder can be reconstituted into fluid milk. It is highly hygroscopic. Whole milk powder can be stored for only six months because of the propensity of fat to oxidise.

Non-fat dry milk powder is usually made from fresh pasteurised skimmed milk by removing about two-thirds of the water under vacuum and then spraying this concentrated milk into a chamber of hot filtered air. This process produces a fine powder of very low moisture content, about 3%. Instant non-fat dry milk disperses readily in cold water. To make the instant product, regular non-fat dry milk is remoistened with steam to induce agglomeration of small particles into larger, porous particles that are creamy white and free flowing. Spray-drying of skimmed milk has less than 10% loss of lysine but roller-drying can produce losses upto 40%. Packing under vacuum or with inert gas increases stability.

The flow chart of manufacture of milk powder is given in Figure 5-e:

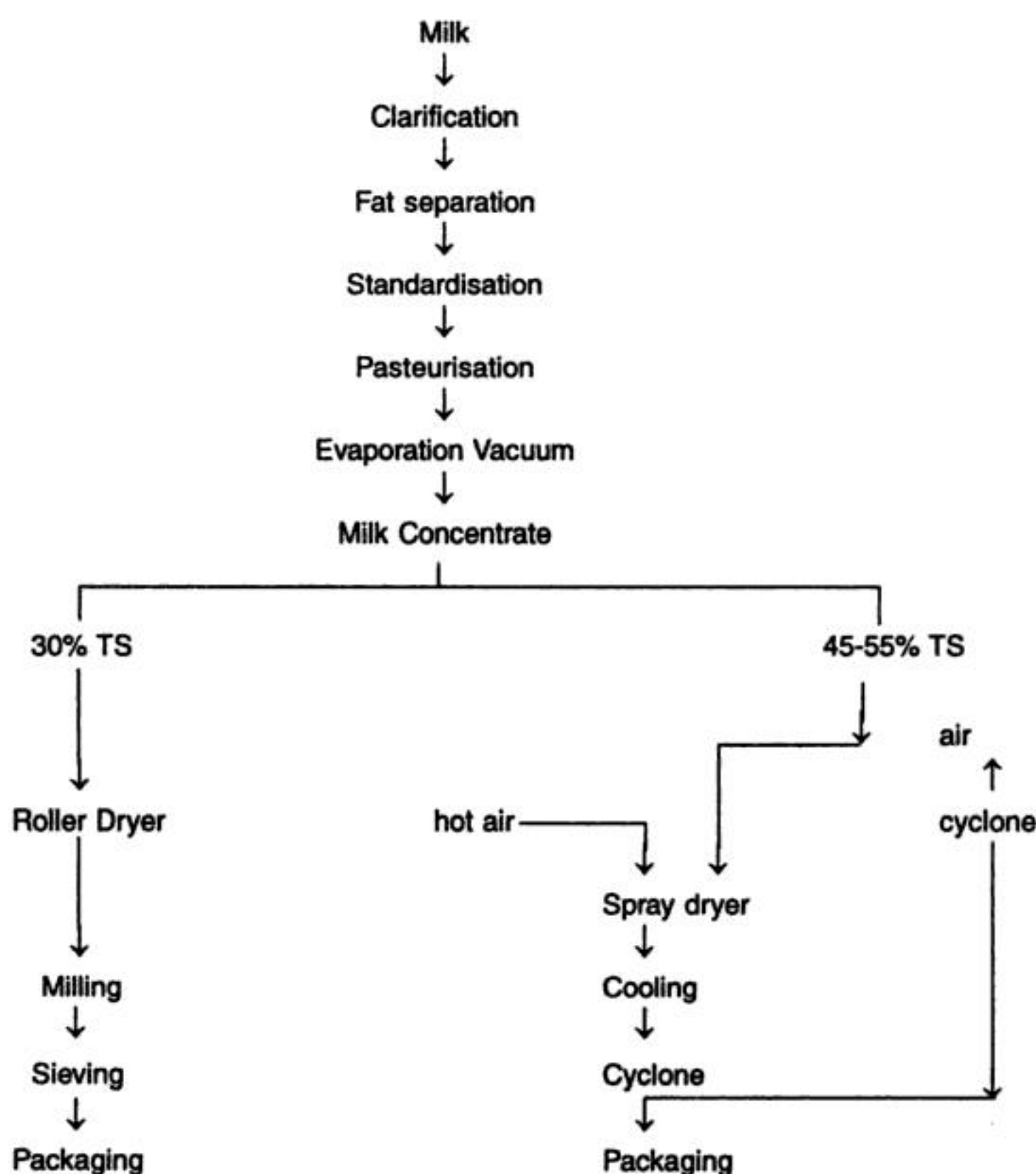



Figure 5-e: Manufacture of milk powder.

Khoa

Khoa is semi-solid obtained from milk by evaporating it in open pans. Milk is cautiously stirred in a circular motion to prevent scorching. When milk becomes viscous the rate of stirring is increased to maintain a uniform consistency. After

cooling it becomes solid. The yield is about 20% of the weight of the milk used.

During the preparation of khoa, all the milk proteins are coagulated. Because of appreciable homogenisation that occurs during vigorous boiling, when coagulation of proteins sets in, all the fat globules are entrenched in the coagulant. Lactose is present as an anhydrous sugar in khoa. There is a decrease in vitamin A and some water soluble vitamins of milk in khoa formation. Buffalo's milk khoa contains 46% fat and cow's milk contains 35% fat.

It is used in the preparation of gulab jamun, carrot halwa and coconut burfi.

Rabri

Is a prepared concentrated and sweetened product comprising several layers of clotted cream. The layer of cream formed as a skin is continuously removed. When the milk is reduced to 1/3 of the original volume, sugar is added.

Chhaina

It is a major heat and acid coagulated product. Chhaina based sweets are rasogolla, sandesh and rasmalai. Cow's milk chhaina is preferred for rasogolla making.

Ice-cream

It is a frozen dairy product consisting of whole milk, skim milk, cream, butter, condensed milk products or dried milk products. Milk fat and milk solids non-fat constitute about 60% of the total solids of the ice-cream. These components give ice-cream a rich flavour, improved body and texture. In addition to dairy products, ice-cream contains sugar, stabiliser, emulsifier, flavouring material, water and air. Sugar, in addition to sweetening affects the smoothness of the resulting ice-cream. It also lowers the freezing point of the ice-cream mix, so that it does not freeze in the freezer.

Stabilisers are used to prevent the formation of ice crystals during freezing. They form gels with the water in the formula and thereby improve the body and texture of the ice-cream. Compounds generally used as stabilisers are gelatin, sea weed or china grass and cellulose derivatives such as carboxy methyl cellulose.

Emulsifiers help disperse the fat globules throughout the mix and prevent them from clumping together during the freezing mixing operation. They further help make the ice-cream dry and stiff. Egg yolk is a natural good emulsifier. Mono and diglycerides are the commercial preparations used. The common flavouring material used in ice-cream is vanilla followed by strawberry, chocolate and coffee. A large number of fruits and nuts are added to improve the taste.

Standardised milk

In standardised milk, the fat content is maintained at 4.5% and S.N.F. at 8.5 per cent. It is prepared from the mixture of buffalo milk and skim milk.

Toned milk

Toned milk is prepared by mixing reconstituted from skim milk powder with buffalo milk containing 7.0 per cent fat. The fat content of the toned milk should not be less than 3 per cent and S.N.F. 8.5 per cent.

Double toned milk

This is prepared by admixture of cow's or buffalo's milk or both with fresh skimmed milk or by admixture with skim milk reconstituted from skim milk powder or by partial removal or addition of milk to skim milk. It should be pasteurised and show negative phosphotase test. Its fat content should be less than 1.5 per cent and S.N.F. not less than 9 per cent.

Recombined milk

Recombined milk is a homogenised product prepared from milk fat, non-fat milk solids and water. It should be pasteurised and show a negative phosphotase test. Its fat content should be less than 3 per cent and S.N.F. 8.5 per cent.

Sterilised milk

Standardised cow's or buffalo's milk is sterilised in bottles by heating continuously to a temperature of 115°C for 15 minutes to ensure destruction of all micro-organisms and preservation at room temperature for not less than 85 days from the date of manufacture. It shall be sold only in the container in which milk was sterilised.

Ultra high temperature (UTH) processed milk

Milk is heated at temperatures higher than those used for pasteurisation, 138°-150°C for 2-6 seconds. Then, under sterile conditions it is packaged into presterilized containers, which are aseptically sealed so that spoilage organisms cannot enter. Hydrogen peroxide may be used to sterilise the milk packaging materials. UHT milk can be stored unrefrigerated for atleast 3 months.

UHT milk has cooked flavour due to denaturation of the whey protein β lactoglobulin. Off flavours develop due to chemical and enzymatic activity. The addition of flavourings to milk masks off flavour.

Filled milk

Filled milk is a homogenised product prepared from refined vegetable oil and non-fat milk solids and water. Its fat content should not be less than 3 per cent and S.N.F. 8.5 per cent.

Flavoured milk

Flavoured milk may contain chocolate, coffee or any other edible flavour, edible food colour and cane sugar. It is either pasteurised or sterilised.

Table 5.3 gives PFA Standards for milk and milk products.

from small cubes is easy. For different type of cheese the curd is cut into different sized cubes.

Curd cooking: Then it is heated to 38°C and held at that temperature for about 45 minutes. During this period the curd is stirred to prevent matting.

Curd drainage: Heating squeezes out whey from the cubes. Heat increases the rate of acid production which makes the curd cubes shrink. Whey is drained off and the curd is allowed to mat.

Cheddaring: Next it is subjected to the process of cheddaring. This consists cutting the matted curd into blocks turning the block at 15 minute intervals and then piling the blocks on one another. During the cheddaring operation which takes about 2 hours, acid formation continues. The cheddared curd is passed through a curd mill which cuts the slabs into strips.

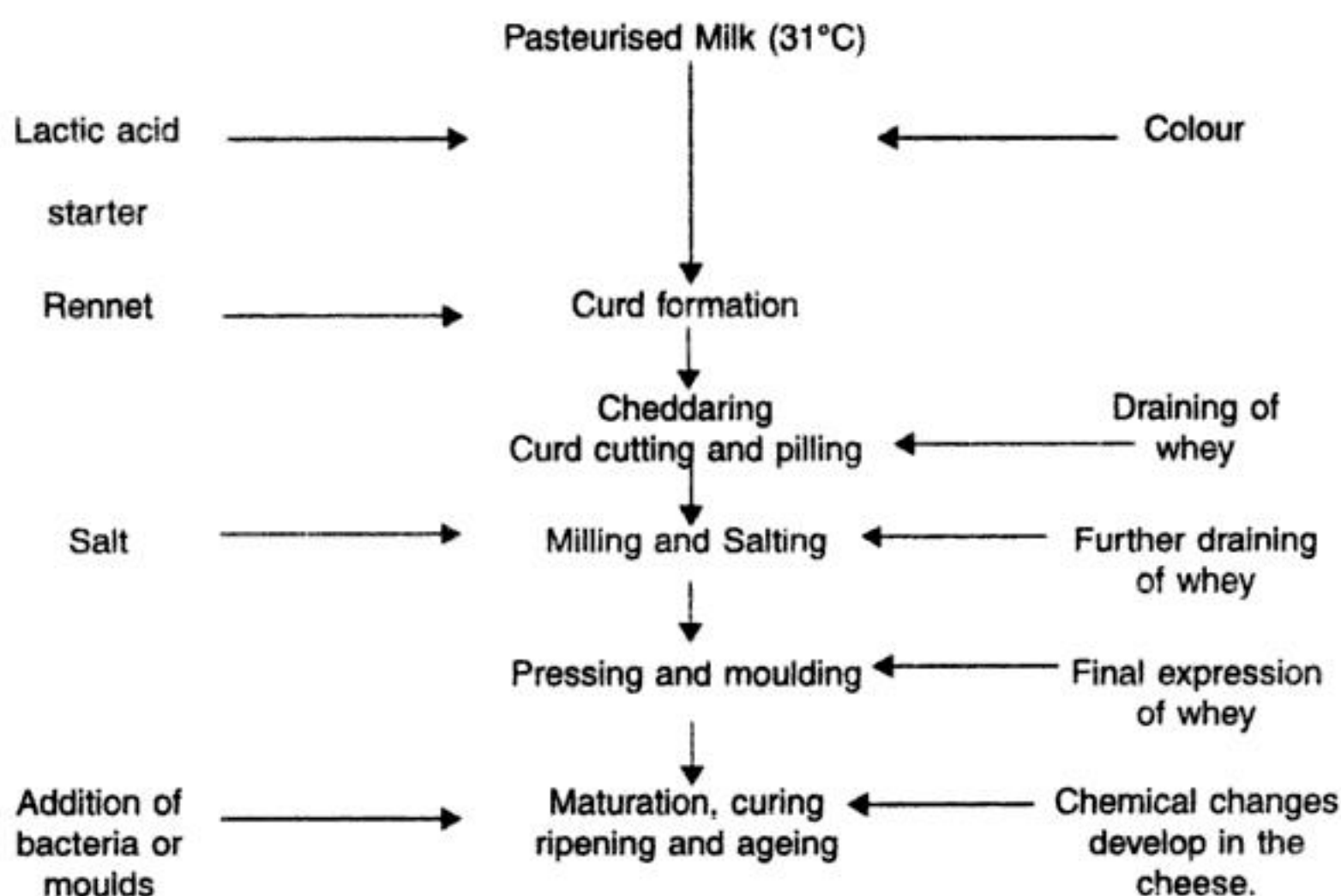



Figure 5-g: The production of cheese.

Source: Robins G.V., 1980, Food Science in Catering, Heinemann, London.

Salting the curd: Whey is eliminated during this process. Salt is added to draw whey out of curd by osomosis and also acts as a preservative. Salt also holds down spoilage of organisms and adds flavour.

Pressing: The cheese cubes are pressed under pressure overnight. This pressing determines the final moisture content of finished product and then the cheese is ripened from 60 days to 12 months depending on the strong or mild flavour cheese required.

Ripening: Ripening takes place under controlled conditions of temperature and humidity for varying periods of time and makes cheese easily digestible. During this process cheese changes from a bland tough rubbery mass to a full flavoured soft product. During ripening rennin splits the protein of cheese into peptones and peptides. Enzymes formed by the micro-organisms act on these and other substances to form products like amino acids, amines,

fatty acids, esters, aldehydes, alcohols and ketones that give its characteristic flavour. There is also increase in B-vitamins during ripening. Ripening also improves the cooking quality. The increased dispersibility of the protein of ripened cheese is a factor in the ease of blending cheese with other food ingredients.

The type of starters used also contribute to flavour and consistency of cheese.

Cheese has limited keeping quality and requires refrigeration, should be kept cold and dry i.e., it should be wrapped in wax paper or metal foil.

Cooking quality: Hydrolysis of the proteins of the cheese occurs during ripening. Cooking quality of cheddar cheese of normal fat content improves as the product of protein hydrolysis is increased.

Moisture content is also related to cooking quality since cheese of high moisture content is superior compared to low moisture cheese.

When fat content is low the tendency for mat formation is exaggerated. The fat of normal samples melted during cooking contributes to the consistency and tenderness of the heated product and preventing the formation of a continuous protein mass. The cooking quality of processed cheese is better than the natural cheese (cottage cheese). The presence of emulsifying agent not only helps in keeping the fat emulsified but increases the alkalinity of cheese which in turn increases the solubility of casein. As casein is rendered more soluble it is less likely to be tough or form firm strings on cooking. It is possible that both ageing and the addition of emulsifying salts improve the cooking qualities of cheese because they make the protein more soluble.

Curd

This is India's most commonly used milk product.

Nutritive value almost remains the same during curd making. The digestibility is better when compared to ordinary milk. Calcium and phosphorus content of curds are more easily assimilated. Curds contain more B vitamins than milk.

During curd formation the lactose of milk is converted into lactic acid. Acid curdles the milk protein. The fat globules coalesce and distribute themselves on the top. Organisms involved in curd formation belong to the group of lacto bacillus and streptococcus. Starter culture containing a combination of lacto-bacillus and streptococcus organisms is good. Starters containing yeasts, moulds and gas containing organisms spoil the quality of curd.

Curd is prepared by initially boiling the milk to destroy viable organisms. It is cooled to the body temperature and 5-10% starter is added. Lesser quantities are needed during summer. After 6-8 hours an acidity of 0.9-1% acid is formed. Due the drop in pH the casein is coagulated and the curd is set. Curd is enjoyed as such and also used in the preparation of kadhi, raita, lassi and shrikhand.

Yogurt is a variety of curd. Whole, low-fat and skim milks and even cream can be used to make yogurt. Often, non-fat dry milk solids are added.

There is increase in folic acid concentration during the fermentation process. In the production of yogurt, a mixed culture of lactobacillus bulgaricus and streptococcus thermophilus, lactobacillus acidophilus is usually added to the pasteurised milk and incubated at 42 to 46°C. Often, yogurt is marketed with sweetened fruit added. Yogurt can be used in lactose intolerance. The fermentation lowers the lactose content by 20-30%.

By churning curd and removing butter, butter milk is obtained. It is used as a beverage for quenching thirst. Powdered butter milk can be made by spray drying.

Metchnikoff postulated that the bacteria involved in yogurt fermentation, lactobacillus bulgaricus and streptococcus thermophilus suppress the putrefective type fermentation of intestinal flora. Fermented milks have been reported to be useful for a wide variety of disorders like colitis, constipation, diarrhoea, gastroenteritis, diabetes and hyper cholesteremia.

Shrikhand

It is another fermented product which is made by concentrating dahi by removing whey and to which sugar, flavour and condiments are added.

MILK SUBSTITUTES

Soyabean milk and groundnut milk are used as substitutes of milk. They are also pasteurised and homogenised before selling in the market. Of course these milks cannot be real substitutes in terms of nutritive value but can be used when there is intolerance for ordinary milk.

FUNCTIONAL PROPERTIES OF MILK

Research strongly supports that a diet high in dairy foods, is an effective strategy for preventings and treating hypertension. Calcium, bioactive peptides and yet unidentified components in whole milk may protect from hypertension.

ROLE OF MILK AND MILK PRODUCTS IN COOKERY

- It contributes to the nutritive value of the diet, e.g., milk shakes, plain milk, flavoured milk, cheese toast.
- Milk adds taste and flavour to the product, e.g., payasam, tea, coffee.
- It acts as a thickening agent along with starch, e.g., white sauce or cream soups.
- Milk is also used in desserts, e.g., ice-cream, puddings.
- Curd or buttermilk is used as a leavening agent and to improve the texture, e.g., dhokla, bhatura.

SUGGESTED READINGS

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- Petczon, M.J. et al., 1993, Microbiology concepts and applications, McGraw Hill Inc.
- Nageswara Rao, R., Milk, Nutrition, *35*, 2, 2001.

QUESTIONS

1. Write a short note on proteins present in milk.
2. How does scum formation occur in milk? Explain.
3. Discuss the factors affecting milk coagulation.
4. What is pasteurisation? Explain the different methods of pastuerisation.
5. Why is pastuerisation carried out on milk? What effect does it have on nutritive value, flavour, microorganisms and on enzymes present in milk.
6. Write a short note on homogenised milk.
7. Describe the different kinds of milk.
8. What are the various fermented and unfermented milk products made out of milk?
9. What is cheese? How is it manufactured? Bring out the nutritional importance of cheese.
10. Describe the role of milk and milk products in cookery.
11. Discuss the points to be remembered while using milk or milk products in cookery.
12. Write short notes on nutritive value of milk.
13. What is coalescence of fat? Where is this principle used?
14. Bring out the importance of whey protein concentrate in cookery.

PRACTICALS

1. Study the factors affecting coagulation of milk protein.
2. Prepare recipes using milk and milk products.
3. Make a survey of different types of milk and milk products available in the market and note the nutritive value from the labels.

Chapter 6

EGGS

Although eggs of all birds may be eaten, the egg of chicken is used more often than any other. The natural function of an egg is to provide for the development of the chick. Its whole structure and composition are designed to fulfill this natural purpose.

STRUCTURE

The different parts of an egg are shown in figure 6-a:
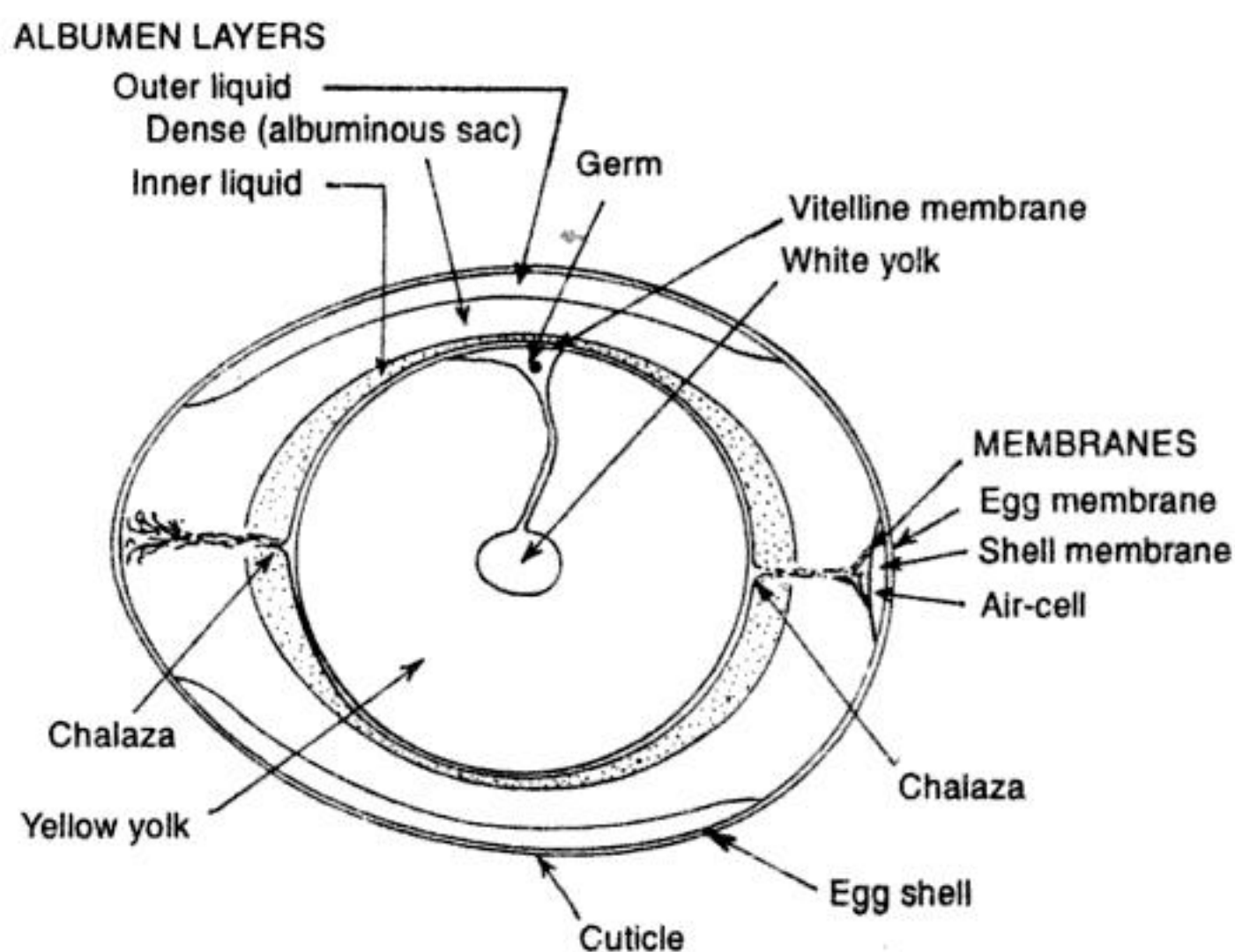
Figure 6-a: Different parts of an egg.

Source: Shakuntala Manay N. and M. Shadakshara Swamy, 2001, Foods, facts and principles, New Age International Publishers, New Delhi.

Shell

It forms the protective covering of the inner contents of the egg along with the two membranes. Shell is made up of protein polysaccharide complex and calcium carbonate. An egg shell is brittle and easily breaks. Some shells are glossy others dull. Some may be smooth and others may be rough.

It is porous and contains thousands of small holes which allow gases to pass in and out of the egg for the developing embryo. The small holes are

covered with a thin layer of gelatinous material mucoprotein called cuticle or bloom. The cuticle seals off the pores of the shell to some extent and helps avoid an excessive evaporation from the inner contents of the egg. It also restricts the entry of microorganisms into the egg and thus protects the inner contents from various infections. The cuticle is soluble in water and easily removed by washing which results in hastening the deterioration of egg quality.

Shell membranes

Within the shell are an inner and outer membrane that also protect the quality of the egg. Both the membranes are porous and composed of fibres. The outer membrane which is thicker (48 μm) than the inner one (22 μm) is firmly attached to the shell. The outer membrane has six layers of fibres, whereas, the inner one has three layers. The inner membrane is attached to the outer and the two membranes are loosely attached to one place usually at the broad end of the egg. The membranes are composed of protein and polysaccharide.

Eggs contain little or no air cells when they are laid. After being laid because of the lower temperature of the outer surroundings of the egg than when it was in the hen's body, there is contraction of the inner contents of the egg. This results in air being drawn into the shell resulting in a small air cell formation between the shell membranes usually at the large end of the egg.

The condition of the shell and the membrane influence moisture and carbon dioxide, breaking strength and susceptibility to microbial invasion.

Egg white

The white of the egg consists of three layers, two areas of thin white encompassing one area of thick white. Some hens secrete a higher ratio of thick to thin white than do others. Storage conditions also affect the thickness of the albumin and the ratio of thick to thin egg white.

Egg yolk

The yolk of the egg is enclosed in a sac called the vitelline membrane. Immediately adjacent to the vitelline membrane, the thin membrane that surrounds the egg yolk, is chalaziferous or inner layer of firm white. This chalaziferous layer gives strength to the vitelline membrane and extends into the chalazae. The chalazae appear as two small twisted ropes of thickened white, one on each end of the yolk and anchor the yolks in the centre of the egg. Chalazae appear to have almost the same molecular structure as ovomucin.

The yolk carries the indistinct germinal disc or germ spot which under suitable conditions develops into a chick. Beneath the germ spot extends a white part called latebra. The yolk itself is layered into sections of white and yellow yolk but they are not readily distinguishable.

In infertile eggs the female reproduction nucleus is not fertilised by union with the sperm of the cock. These are incapable of producing chicks and therefore called lifeless or vegetarian eggs. Infertile eggs are produced when a male bird is not kept with the laying hens.

COMPOSITION

The distribution of weight of egg is given in Table 6.1:

Table 6.1: Percentage distribution of components of egg

Part	*Weight*
Shell	8-11
White	56-61
Yolk	27-32

Egg shell

It is primarily calcium carbonate deposited in an organic matrix. The composition of egg shell is given in Table 6.2. This portion of the egg is inedible.

Table 6.2: Percentage composition of egg shell

Component	*Per cent*
Calcium carbonate	93.07
Magnesium carbonate	1.39
Phosphorus pentoxide	0.76
Organic matter (matrix protein and polysaccharide)	4.15

The composition of egg white and yolk differ considerably. The lipid content of albumin is negligible when compared to yolk. A very small amount of glucose is present in the egg white. Table 6.3 gives percentage composition of egg white and yolk.

Table 6.3: Percentage composition of egg white and yolk

Nutrients	*Egg White*	*Egg yolk*
Water	88.0	48.0
Protein	11.0	17.5
Fat	0.2	32.5
Minerals	0.8	2.0

Egg white

Egg white is composed of thin and thick portions. 20-25% of the total white of

fresh eggs (1-5 days old) is thin white. The chief constituents of egg white besides water are proteins. Different types of proteins are present in egg white.

Ovalbumin: This constitutes 55% of the proteins of egg white. This is a phosphoglycoprotein and is composed of three components A_1, A_2 and A_3 which differ only in phosphorus content. The relative proportion of A_1, A_2, A_3 component is about 35:12:3. The carbohydrate component of ovalbumin are mannose and glucosamine in the ratio of 5:3. Ovalbumin in solution is readily denatured simply by mechanical agitation (whipping) but is resistant to thermal denaturation. At pH 9 and at 62°C only 3-5% of ovalbumin is denatured.

Conalbumin: This constitutes 13% protein of the egg albumin. It consists of two forms neither of which contains phosphorus nor sulphur. Conalbumin is more easily heat coagulated and less susceptible to surface denaturation than ovalbumin. The protein easily binds metallic ions such as iron, copper, aluminium, zinc forming heat stable complexes.

Ovamucoid: It is a glycoprotein. This constitutes about 10% of the egg white proteins. It exists in three forms and all of which are trypsin inhibitors. It is resistant to heat denaturation in acid media but is rapidly denatured in alkali solution.

Ovomucin: This protein is responsible for the jelly-like character of egg white and the thickness of the albumin. It contains 2% of the egg white. Its content in the thick layers of albumin is about 4 times more than in thin layers. It is insoluble in water but soluble in dilute salt solution. Purified ovomucin in solution is resistant to heat denaturation. It is a very large molecule with a filamentous or fibre-like nature.

Lysozyme: 3.5% of the egg white protein is lysozyme. This is an enzyme capable of lysing or dissolving the cell of wall of bacteria. It is heat sensitive. Hen's egg white has three to four times more lysozyme than does duck egg white.

Avidin: This protein is 0.05% of the egg white protein. It is composed of 3 components A, B and C. It binds biotin and makes the vitamin unavailable. Avidin is denatured by heat and cooked eggs do not affect the availability of biotin.

Ovoglobulin: It is a protein consisting of two components G_1 and G_2 and both are excellent foaming agents.

Ovoinhibitor: 0.1% of egg protein is made up of ovoinhibitor. It is another protein capable of inhibiting trypsin and chymotrypsin. Summary of egg white proteins is given in Table 6.4.

Egg yolk

Solid content of yolk is about 50%. Yolk is a dispersion containing a variety of particles distributed uniformly in a protein solution. On high speed centrifugation yolk separates itself into granules and a clear supernatant called plasma. Granules are composed of 70% α and β lipovitellins, 16% phosvitin and 12% low density lipoprotein. Phosvitin, lipovitellin complex is a basic unit of granules. Plasma is composed of the globular protein livetin and a low density lipoprotein fraction.

The major proteins in egg yolk are lipoproteins which include lipovitellins and lipovitellinin. The lipoproteins are responsible for the excellent emulsifying properties of egg yolk, when it is used in such products as mayonnaise.

Table 6.4: Proteins in egg white

Protein Isoelectric point	*Type*	*Comment*	*Cooking properties*
Ovalbumin pH 4.6-4.8	Fibrous	70% of white protein.	Readily denatures
Conalbumin	Globular	Interferes with absorption of iron.	Coagulated by heat
Ovomucoid pH 3.8-4.5	Glycoprotein	Trypsin inhibitor	Resistant to heat, denaturation in acid.
Ovomucin	Conjugated fibrous forms	Conjugated with carbohydrate structural basis of thick white	Resistant to heat denaturation, stabilises egg white foams.
Lysozyme pH 10.5-11	Globular	Natural bactericide protecting the egg from bacterial invasion.	It is heat sensitive, has foam forming property.
Avidin pH 10.0	Basic protein	Combines with biotin, render it unavailable.	Becomes inactive by cooking.

Lipovitellins: These are high density lipoproteins comprising 16 to 18% of egg yolk solids. They can be separated into two fractions α and β lipovitellins. Each fraction contains 40% neutral lipids and 60% phospholipids.

Phosvitin: This comprises 5-6% of yolk solids. This is rich in phosphorus and accounts for 80% of the protein phosphorus of yolk. It is rich in serine and phosphate is esterified to this amino acid. Phosvitin binds tightly ferric ions and forms a soluble complex and is thus the iron carrier of the yolk.

Livetin: This comprises 4-10% of yolk solids. This consists of three components α, β and γ livetins. This is a water soluble protein and is rich in sulphur. Components of this protein differ in their molecular weight.

Low-density lipoprotein: Low-density lipoprotein of egg yolk has a density of 0.98. It consists of 74% neutral lipids and 26% phospholipids. It can be separated into components LDL_1 and LDL_2.

A number of enzymes are also present in the protein fraction.

Fat in the egg yolk

It contains triglycerides, phospholipids and lipoproteins. Lipoproteins are

complexed with phospholipids and cholesterol. The main phospholipids is lecithin. The main fatty acids in the triglycerides of the egg yolk are oleic, palmitic and linoleic and stearic in order. Table 6.5 shows fatty acid composition of egg yolk.

Table 6.5: Fatty acid composition of egg yolk

Fatty Acid	*% of total fatty acids*
C_{16}: 0 Palmitic acid	23.5
C_{18}: 0 Stearic acid	14.0
C_{18}: 1 Oleic acid	38.4
C_{18}: 2 Linoleic acid	16.4
C_{18}: 3 Linolenic acid	1.4
C_{20}: 4 Arachidonic acid	1.3

In view of the presence of highly unsaturated fatty acid in egg yolk fat, it is prone to undergo oxidation easily and develop off flavour.
Egg yolk viewed under the microscope is seen to consist of a relatively a small number of larger spherical bodies called granules and numerous smaller less regular shaped bodies called mycelles. Both granules and mycelles are suspended in the liquid or plasma portion of the yolk. Egg yolk does not contain free fat as such in spite of its high content of triglycerides. Instead most of the triglycerides and a high proportion of the phospholipids are found in the mycelles. Mycelles contain an encased layer of phospholipid surrounding a layer of protein. Thus these mycelles are in the nature of micro emulsion. Almost 90% of the fat of the egg is found in these mycelles.

PIGMENTS

Shell: The colour of the shell is white in majority of the breeds. Sometimes it is in shades of brown, depending upon the breed. Colour does not indicate quality or the nutritive value.

Egg white: Egg white contains small amounts of ovoflavin due to which a greenish tinge can be seen. The more the riboflavin in the egg white, the greener is the colour.

Egg yolk: The colour of the egg yolk varies from a pale yellow to brilliant orange depending upon the amount and type of the pigment present in the diet of the hen. The colour is due to the presence of carotenoids and xanthophylls. The carotenoids can be converted into vitamin A in the body. Mostly deep coloured yolks are rich in vitamin A content. Xanthophylls are responsible for the yellow colour and are not converted to vitamin A. If the hen is fed with pure vitamin A, the yolk may be rich in vitamin A but there may not be any colour.

NUTRITIVE VALUE

Eggs are rich source of all nutrients except ascorbic acid. Nutritive value of egg is given in Table 6.6.

Table 6.6: Nutritive value of egg/100 g

Nutrient	*Amount*	*Nutrient*	*Amount*
Energy kcal.	173.0	Carotene µg	600*
Protein g.	13.3	Thiamine mg.	0.1
Fat g.	13.3	Riboflavin mg.	0.4
Calcium mg.	60.0	Niacin mg.	0.1
Phosphorus mg.	220.0	Folic acid µg	78.3
Iron mg.	2.1	Vitamin B_{12} µg	0.2

* + 360 µg of vitamin A. (0.6 µg of carotene = 0.3 µg of vitamin A)

Proteins

Egg contains 12-14% proteins which are well balanced with respect to all the essential amino acids. Hence it is used as standard against which the chemical score of other proteins is compared.

The contents of two eggs provide nearly 25% of daily protein requirements of an adult man. Besides egg proteins have an excellent supplementary value to all other plant protein foods. For example, cereal proteins are poor in amino acid, lysine. Pulses and oilseed proteins are poor in sulphur containing amino acid cysteine. Hence a combination of egg with any of the cereal or cereal pulse mixture will enhance the protein quality of food.

Table 6.7: Nutritive value of proteins from different foods

Foodstuff	*Biological Value*
Egg	96
Milk	90
Fish	80
Rice	80
Meat	74
Bengal gram	74
Red gram	72
Wheat	66
Gingelly seeds	62
Ground nut	55
Maize	50

Source: Gopalan, C., B.V. Rama Sastri and S.C. Balasubramanian, 1999, Nutritive value of Indian foods, National Institute of Nutrition, Indian Council of Medical Research, Hyderabad-500 007.

The biological value of egg protein is the highest among the proteins from various foods.

Fat

Egg is one of the richest sources of lecithin—a phospholipid which forms a part of the structure of every cell wall in the body. Besides contributing to energy it is the source of essential fatty acids, linoleic acid and arachidonic fatty acids. Vitamins A, D, and E are present in the yolk and egg fat also acts as the vehicle for these fat soluble vitamins. Egg fat is in highly emulsified form hence it is readily digested and absorbed.

On an average each egg contains 250 mg of cholesterol and the permitted intake is 300 mg of cholesterol per day. Three to four eggs per week can be consumed by normal persons without any adverse effect.

Minerals and vitamins

There is a strong relationship between the mineral content of the hen's diet and the concentration of minerals in the egg. Calcium is the most abundant mineral in the whole egg but it is concentrated in the shell. Important minerals such as phosphorus, iron, zinc and other trace elements are present in the egg. Egg is a rich source of biologically available zinc. Egg iron is bound to conalbumin and poorly absorbed in man.

Except for vitamin C which is totally absent in the egg, other water soluble as well as fat soluble vitamins are present in the egg in appreciable amounts. Egg is particularly rich in vitamin A, riboflavin, folic acid and B_{12}. The amount of these vitamins in the egg depends upon these nutrients present in the feed of the bird.

Modifying nutrient composition

The nutritive value of the egg can be changed by manipulating the diet of the hen. Protein content cannot be changed much but addition of liquid oils to the hens diet, can increase the fat content of the egg. Exposure of the birds to sunshine or addition of vitamin D to the feed improves the vitamin D content of the egg. Vitamin D deficiency in the hen reduces egg output. Even cholesterol content of egg yolk can be reduced by feeding fish oil to the hen's diet.

No difference in nutritive value is noted between infertile and fertilised eggs.

Effect of cooking on nutritive value of egg

By cooking egg there is little or no change in the nutritive value of protein, minerals or the fat soluble vitamins except there is some loss of thiamine and riboflavin. In hard cooked eggs, fried, poached and scrambled eggs the retention of riboflavin and thiamine is more than 85%. Heating egg white improves the availability of biotin as avidin gets denatured.

QUALITY OF EGG

Egg is an excellent food and hence its quality is of very great importance.

Fresh eggs have best quality. Quality of egg can be determined by many factors.

Size

By weight we can find out the quality. The normal weight of an egg is 40-70g. The weight depends on the inheritance, stage of laying, season of laying, age, diet and health of the bird. Size does not reflect the quality. Usually small eggs contain higher proportion of yolk than large eggs.

Shell

Though this part is not consumed its condition is important because of the protection it gives to the edible portion. The factors to be considered are its strength, porosity and cleanliness. The strength of the shell depends upon its thickness which in turn depends on the nutrition of the bird. A high porosity of the egg shell will hasten the deterioration on the quality of egg contents as it permits the evaporation of moisture and allows dissolved carbon dioxide to escape from the contents during the storage of egg. The texture of the shell does not affect the quality of inner content. Any dirt on the egg shell means the presence of the large number of contaminating microorganisms. Weak shells, rough handling results in damage to the shell. Good egg should be unbroken.

Air cell

As the quality of the egg deteriorates the size of the air cell increases due to loss of moisture through the cell especially in warm, dry atmosphere. In good quality egg the depth of the air cell is 1/8-3/16 inches. In poor quality the depth of the cell would be more than 3/8th of an inch.

Egg white

A fresh egg when broken on to a plate stands up in rounded form due to the viscosity of the thick portion of the egg white that surrounds the yolk. As egg deteriorates the percentage of the thin white increases. Possibly due to proteolysis, reduction of S-S bonds and interaction of mucin and lysozyme. The increase in thinning correlates with an increase in alkalinity and alkaline hydrolysis of the disulphide bonds of ovomucin to yield a lower molecular weight protein. As the quality deteriorates the pH of white increases from 7.6 to 9.7. There is loss of carbon dioxide also. Increased alkalinity also decreases the volume of cakes.

Egg yolk

In deteriorated egg the yolk also takes up water from the white and the yolk membrane i.e., vitelline membrane stretches and when broken on to a plate the deteriorated egg flattens and tends to spread over the plate. If stretched excessively by movement of water into the yolk, the yolk membrane is weakened and may break when the egg is removed from the shell. Separation of the yolk from the white is thus difficult or impossible. Yolks of fresh eggs are slightly acid pH, that is, 6-6.2 and as there is increased loss of carbon dioxide,

alkalinity is increased. The pH of the eggs may be kept lowered or less alkaline during storage if the egg shells are coated with a thin layer of oil.
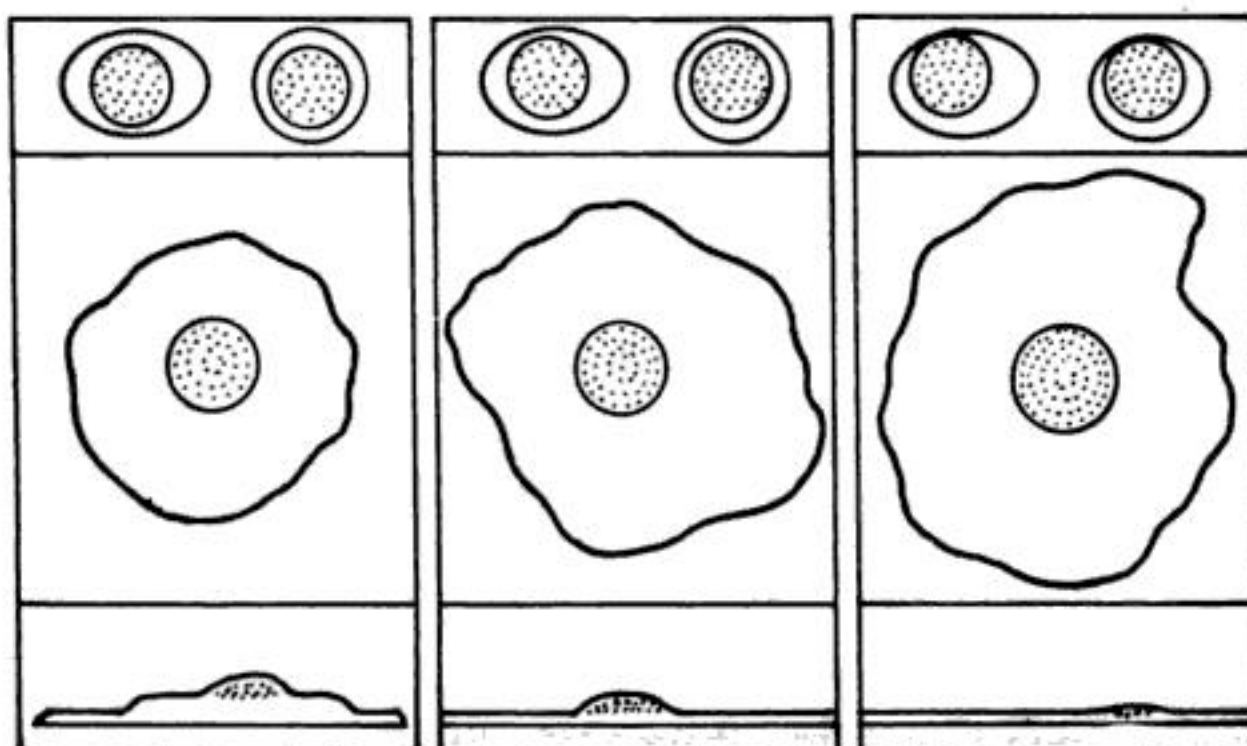
Figure 6-b: Quality of egg.

Source: Kinton Ronald and Victor Ceseram, 1989, The theory of catering, ELBS, Churchill Livingstone

Chalazae

As egg deteriorates they start to disintegrate and cannot hold the yolk in the centre of the egg.

EVALUATION OF EGG QUALITY

Candling

The quality of the egg in the shell is evaluated by candling. The egg is held against a source of strong light. Candling wili reveal:

(a) a crack in the shell.

(b) the size of the air cell.

(c) the firmness of albumin.

(d) the position and mobility of yolk and

(e) the possible presence of foreign substances like blood spots, moulds and developing embryo.

As the eggs deteriorate, the chalaza weakens and the yolk tends to settle toward the shell rather than remain suspended in the firm white. Under such circumstances the yolk is more fully visible when the egg is candled. Dark yolks cast a more distinct shadow than light coloured yolks.

Although candling is the best available method for rating unbroken eggs it may not be totally reliable.

Floating in water

If the egg sinks it is considered as good. Poor quality eggs float due to increase

in size of the air cell and due to loss of moisture.
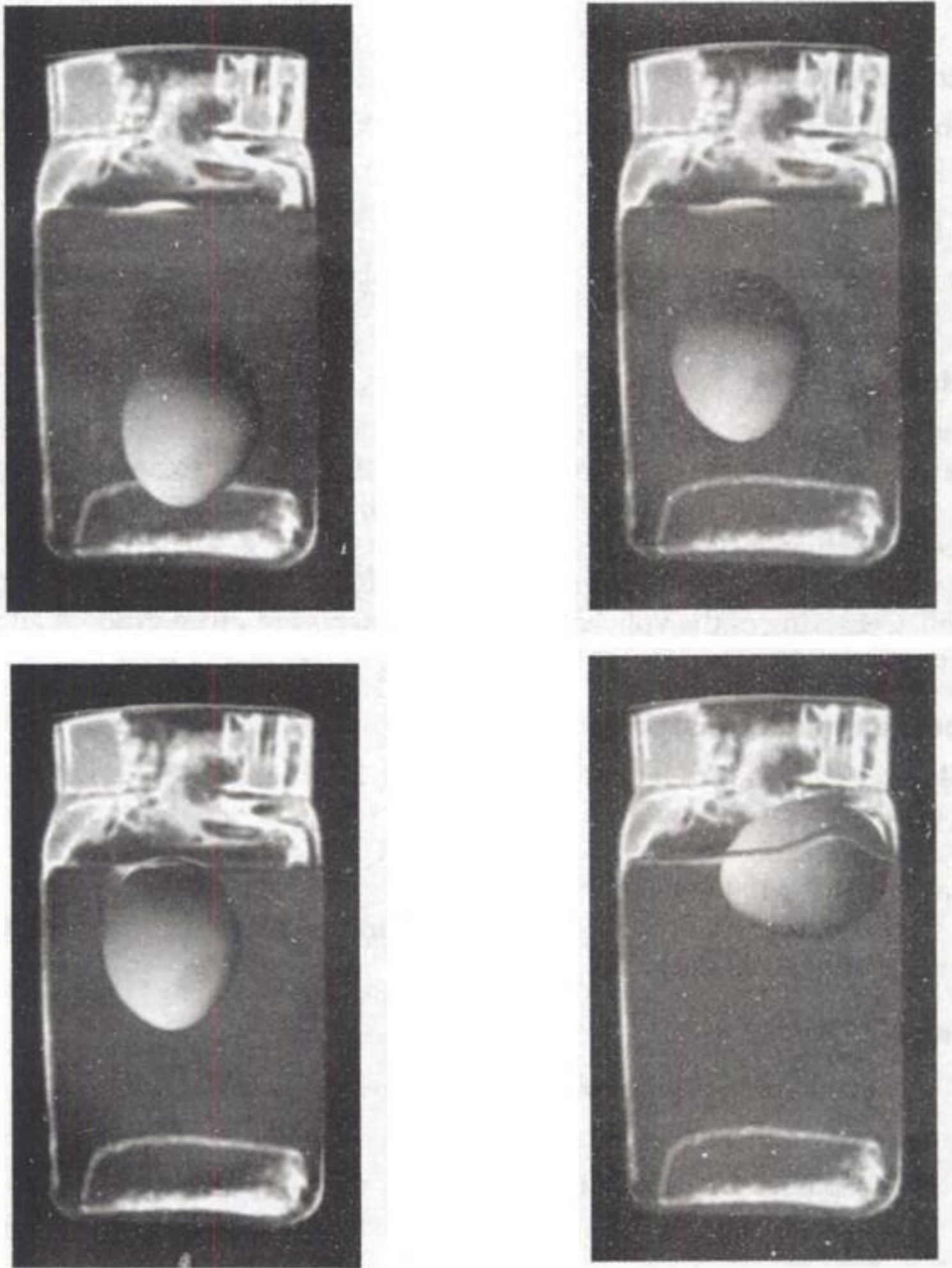
Figure 6-c: Floating test to evaluate the quality of egg.

To test the freshness of an egg, plunge it into a 12 per cent solution of salted water: A fresh egg falls at once to the bottom; An egg 2 days old floats midway; An egg 4 days old rises to the surface; A 2-week old egg floats on top.

Source: New Larousse, 1983, Gastronomique—The world's greatest cookery reference book, Prosper Montague publishing group Ltd. Hamlyn, London.

Haughs Unit

Measurement of the height of the thick white in relation to the weight of the

egg gives haughs unit. Good quality egg has 72 haugh units and as the quality deteriorates it comes down to 36-60. Micrometer is used to measure the height of thick white.

White Index

The height of the thickest portion of the white is divided by the diameter of the egg gives white index.

Yolk Index

Measurement of the height of the yolk in relation to the width of the yolk gives the yolk index.

Grading

The interior quality of the egg deteriorates from the time it is laid to until it is consumed. With proper care, however, this decline in quality can be minimised.

In India eggs are graded according to the weight into 4 grades. Extra large—more than 60 g, large—53-59 g, medium—45-52 g, small—38-42 g. Clean eggs with unbroken shell are graded on quality depending upon depth of the air cell. Centering of the yolk and free from defects are given grade A and B in India.

Deterioration during storage

Fertile eggs get deteriorated more rapidly than infertile eggs. Eggs when stored at room temperature undergo deteriorative changes. The weakening of the yolk membrane occurs after 2 days storage at 37°C, or after 5 days at 25°C, or 20 days at 16°C, 100 days at 2°C.

These changes that occur during deterioration may be grouped as physical and chemical changes.

Physical Changes

- Egg white becomes less viscous and spreads rapidly.
- The size of the air cell increases.
- Water passes from the white to the yolk thus increasing the volume and water content of the yolk resulting in breaking of vitellin membrane.

Chemical Changes

- Loss of water.
- Loss of carbon dioxide.
- Change in pH 7.6 to 9.7 in egg white.
- The breakdown of proteins.
- Increase in the amount of free ammonia.
- Increase in water soluble inorganic phosphorus.
- Increase in free fatty acid in yolk fat.

Food Science

Third Edition

The book presents a clear and systematic account of the composition and nutritive value of different types of foods. Cereals, pulses, nuts, milk, vegetables, fruits and spices have been discussed in considerable detail.

Fats and oils, sugar and various beverages and appetisers have also been explained.

Separate chapters have been devoted to eggs and flesh foods.

Ways of evaluating food quality alongwith food preservation have been explained in detail.

Various food laws and standards in relation to adulteration have been highlighted alongwith the recent trends in food technology.

With its detailed coverage and simple style of presentation, this is an essential text for Home Science students. This book is also a valuable reference source for anyone interested in knowing more about food and nutrition.

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She has also authored the book *Nutrition Science*, which is used as textbook at undergraduate level by all the Indian universities.

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